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Technical Report 834

A Simulation-Based Evaluation of a Position Navigation System for Armor: Soldier Performance, Training, and Functional Requirements

Robert S. Du Bois and Paul G. Smith
Universal Energy Systems, Inc.

April 1989

United States Army Research Institute for the Behavioral and Social Sciences

U.S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

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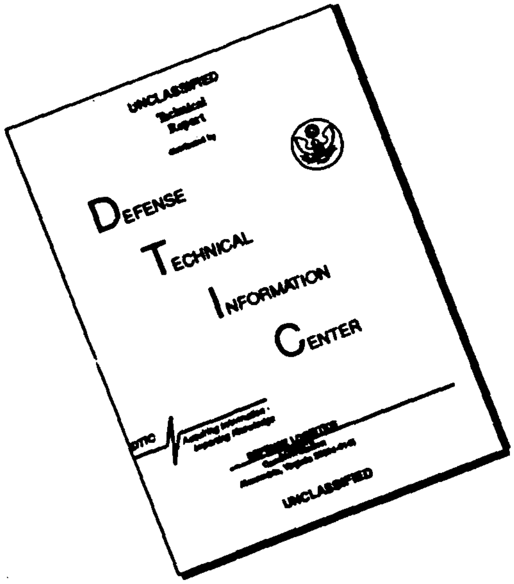

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The Army is investigating the utility of including an automated Position Navigation (POSNAV) system in the Block II M1A1 tank. Researchers evaluated a prototype POSNAV system by assessing the simulation-based performance of 15 Armor platoons and 60 tank crews in two different display formats. The research compared the performance of crews and platoons using either a POSNAV grid or terrain map display with the performance of crews and platoons using conventional navigational tools, including a paper map, compass, and protractor. Findings strongly support including a POSNAV display in future tank upgrades. Armor crews and platoons equipped with POSNAV performed significantly better than crews and platoons using conventional navigational techniques. POSNAV-equipped crews and platoons completed marches and combat missions more quickly, used less fuel, and reported checkpoints and enemy and own-tank locations faster and more accurately than crews and platoons using conventional tools. Few significant performance differences were detected

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between the POSNAV grid and terrain map display conditions. POSNAV issues addressed in this report include soldier performance and training implications, user acceptance, functional requirements, and potential combat, combat service, and combat service support effects.

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A Simulation-Based Evaluation of a Position Navigation System for Armor: Soldier Performance, Training, and Functional Requirements

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FOREWORD

To assist the United States Army in achieving maximum effectiveness on the future AirLand battlefield, the Army Research Institute for the Behavioral and Social Sciences (ARI) performs behavioral research on soldier performance issues related to new combat weapon systems. Within the ARI Field Unit at Fort Knox, the Future Battlefield Conditions Team conducts applied research to enhance soldier preparedness by evaluating "soldier-in-the-loop" performance when using prototype Armor weapon systems. ARI's involvement in research on future battlefield conditions supports the memorandum of understanding between ARI and the U.S. Armor Center and School on Land Battle Test Bed Research signed 9 January 1986.

This report provides data on the performance of soldiers using a new automated navigational system, the Position Navigation (POSNAV) system, in the Block II M1A1 tank. The results of this evaluation provide Armor commanders, combat developers, and combat modelers data concerning the potential Armor combat performance contributions, training implications, and functional requirements of a POSNAV system.

Results of this effort were briefed to the Directorate of Combat Developments and, in turn, by the Commanding General of Fort Knox to the Chief of Staff of the Army to support Block II M1A1 improvements. In addition, results were provided to the POSNAV Integration Office at the Combined Arms Center for distribution to numerous Army agencies. Training and soldier-machine-interface findings were provided to General Dynamics Land Systems, prime contractor for the M1A1 tank, in support of their Block II developmental efforts. Results were also presented at the annual Military Testing Association Conference, November 1988.

EDGAR M. JOHNSON
Technical Director

A SIMULATION-BASED EVALUATION OF A POSITION NAVIGATION SYSTEM FOR ARMOR: SOLDIER PERFORMANCE, TRAINING, AND FUNCTIONAL REQUIREMENTS

EXECUTIVE SUMMARY

Requirement:

To improve Armor land navigation performance, the Army is evaluating the utility of including an automated navigational system, the Position Navigation (POSNAV) system, in the Block II M1A1 tank. The present research evaluates the POSNAV system as represented in the Army's advanced test bed, Simulation Networking-Developmental (SIMNET-D), by assessing soldier performance using alternative display formats.

Procedure:

An among-groups multivariate analysis of variance (MANOVA) design was used. Five tank platoons were randomly assigned to each of three experimental groups: (a) a control (or no POSNAV) group, (b) a POSNAV grid map display group, and (c) a POSNAV terrain map display group. Each platoon completed a 1-day training program and 2 days of testing. The soldiers completed four crew-level tactical road march exercises and two offensive platoon-level combat mission exercises on the SIMNET-D battlefield.

Findings:

Tank crews and platoons equipped with POSNAV performed significantly better than control crews on 32 of 36 performance measures. Few significant differences were detected between the POSNAV grid map and terrain map display conditions.

Utilization of Findings:

The results of this research support including a POSNAV display in the upgraded Block II M1A1 tank. The soldier performance data bases generated from this research, particularly for platoon combat mission performance, provide commanders, combat modelers, and combat developers a basis for deriving estimates of POSNAV's potential effect across a wide range of combat, combat service, and combat service support measures. These results also describe soldier reactions to the POSNAV soldier-machine-interface and identify POSNAV research and training issues.

A SIMULATION-BASED EVALUATION OF A POSITION NAVIGATION SYSTEM FOR ARMOR: SOLDIER PERFORMANCE, TRAINING, AND FUNCTIONAL REQUIREMENTS

CONTENTS

LIST OF TABLES

LIST OF FIGURES

A SIMULATION-BASED EVALUATION OF A POSITION NAVIGATION SYSTEM FOR ARMOR: SOLDIER PERFORMANCE, TRAINING, AND FUNCTIONAL REQUIREMENTS

Introduction

The United States Army has a major concern in ensuring that its armored weapon systems achieve their maximum capabilities on the future AirLand battlefield. Continuous efforts have been and are being made by the U.S. Army to implement new technologies to enhance the firepower, mobility, and survivability of Armor systems. To improve Armor land navigation performance, the Army is currently evaluating the utility of including an automated navigational system, the Position Navigation (POSNAV) system, in the Block II M1A1 tank.

POSNAV's informational display will provide Armor commanders with automated, accurate updates of critical position navigation information, such as own-vehicle location and hull and turret heading, embedded in an analog spatial display. This type of information is required for effective tank land navigation. Navigation, the process of moving from one location (e.g., an assembly area) to another location (e.g., an objective), is key to Armor combat success (Field Manual (FM) 21-26). POSNAV is expected to significantly enhance a tank commander's ability to navigate in a complex battlefield setting, like the setting expected in a future AirLand Battle (FM 100-5).

Presumably, commanders with POSNAV will spend less time manually calculating critical position navigation data with a paper map, protractor, and compass, as they do now, and more time performing other mission requirements, such as planning missions and routes, maintaining command and control, and acquiring targets. Nevertheless, despite the pertinent navigation information it will provide, POSNAV may be a hindrance rather than a help to Armor commanders if the system's interface results in users' confusion, misinterpretation, or error.

To simulate and evaluate new Armor capabilities, the Army is currently using the Simulation Networking-Developmental (SIMNET-D) experimental test bed located at Fort Knox, Kentucky. POSNAV is one of the first Armor developmental systems to be evaluated in the SIMNET-D test bed.

The present research evaluates the POSNAV system, as represented in SIMNET-D, by assessing tank crew and platoon performance as function of two different display formats. These alternative formats are (a) POSNAV functions integrated with a grid map display and (b) POSNAV functions integrated with a terrain map display.

At the time of this evaluation, POSNAV was expected to be a principal component of the Intervehicular Information System (IVIS), a computer-based information management system proposed to significantly enhance lower echelon command, control, and communication (C^3) performance. While the grid map display format is currently anticipated in the first generation of IVIS, the more costly terrain map format is projected for future IVIS generations (Lickteig, 1986, 1988). To ensure a more comprehensive assessment of potential POSNAV variants, both formats were included in this evaluation.

This research compared the performance of tank crews and platoons using either the anticipated grid or terrain map POSNAV displays with the performance of crews and platoons using conventional navigational tools, such as a compass, protractor, and paper map. The research focused on soldier performance using simulated POSNAV capabilities and not on the engineering and hardware requirements for actual, non-simulated system development.

The goals of the research were to (a) determine the potential Armor crew and platoon performance effects of POSNAV, (b) identify potential implications of POSNAV on Armor training, and (c) evaluate soldier reactions to, or functional requirements of, a POSNAV soldier-machine-interface (SMI).

Background

As the present research uses the SIMNET-D facility and its resources, it is important that readers understand this test bed's research and development capabilities. In the sections that follow, literature pertaining to SIMNET-D and the POSNAV system is reviewed. Literature relevant to assessing tank crew and platoon performance is also summarized.

The SIMNET-D Experimental Test Bed

The SIMNET Project

SIMNET-D is one product of an advanced technology project, the SIMNET project, sponsored by the Defense Advanced Research Projects Agency (DARPA) in close cooperation with the U.S. Army. The program's objective is to develop a Department of Defense technology base for extended local and long-haul networking of low-cost, full-crew combat system simulators with each supported by its own set of microprocessors (Bolt, Beranek, & Newman (BBN) Laboratories, 1986; Miller & Chung, 1987; Perceptronics, 1986b).

Figure 1 provides a layout of SIMNET's distributed networking, including the general layout of the various soldier-

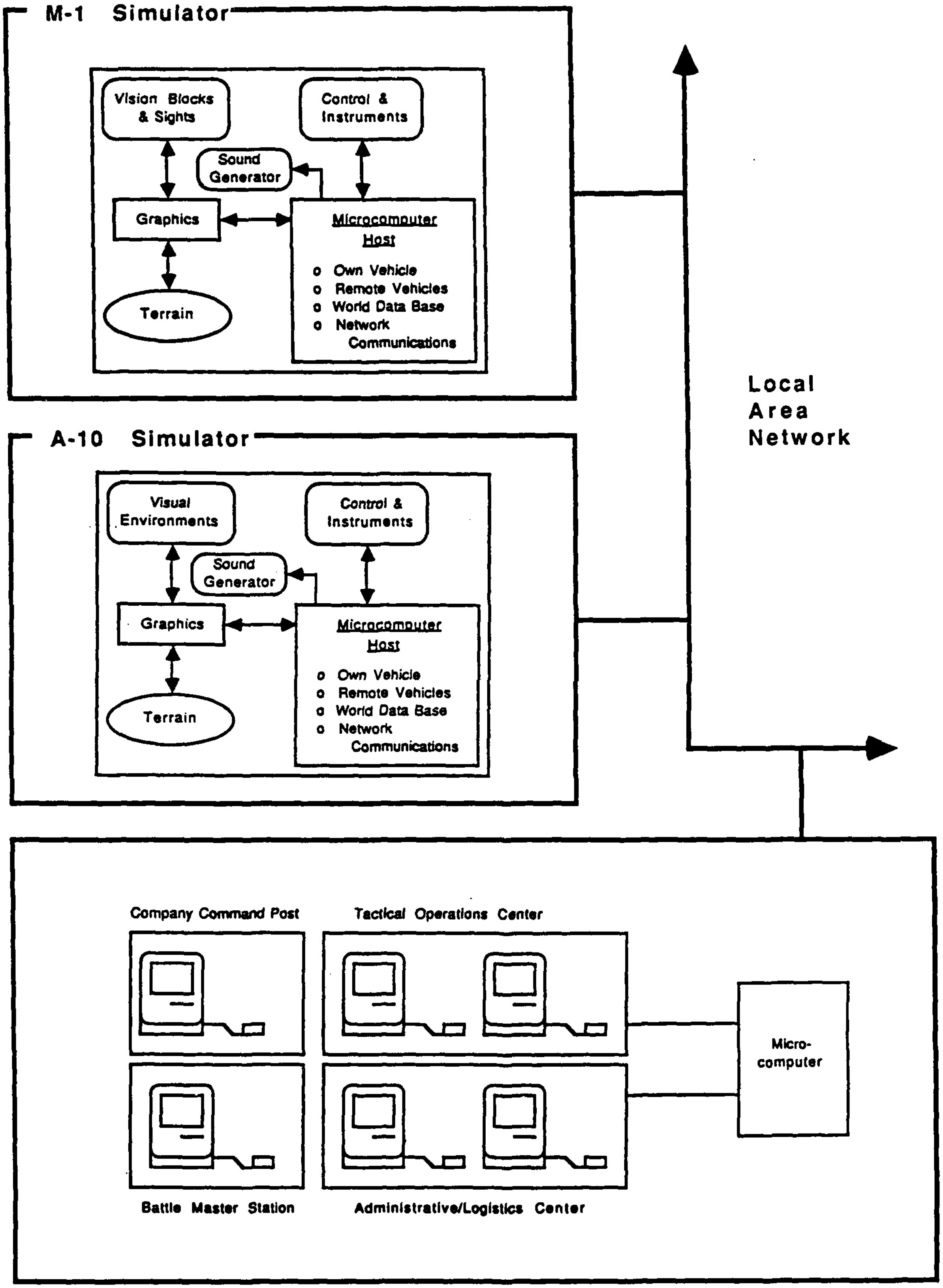

Figure 1. Basic layout of SIMNET distributed networking.

in-the-loop weapon system modules (e.g., the M1 tank and A-10 jet simulators), as well as tactical, administrative, and logistical support elements. This network provides distributed, multi-player, real-time, and continuous combat exercise capabilities.

One of the primary thrusts of the SIMNET project is the development of a simulation-based training center, SIMNET-Training (SIMNET-T), where Army battalions and smaller units can conduct exercises and drills that include the critical tactical, logistical, and communicational elements of actual combat operations. These exercises can be organized and conducted to reduce--if not eliminate--the substantial logistical costs of transportation, set-up, execution and maintenance unavoidable in current combat field exercises with operational combat equipment, such as those exercises conducted at the U.S. Army's National Training Center (NTC).

The SIMNET technology has also been configured to form an experimental test bed, SIMNET-D. This test bed permits the test and evaluation of new technologies and tactics for combat weapon systems (BBN Laboratories, 1986; Miller & Chung, 1987). In particular, the soldier-in-the-loop nature of SIMNET provides an excellent test bed for research related to human factors, manpower, personnel, and training issues (Black & Quinkert, 1987).

In support of the different missions for SIMNET-T and SIMNET-D, there is also a principal difference between the SIMNET-T and SIMNET-D simulators. SIMNET-D utilizes more reconfigurable simulators, allowing combat developers to add or subtract both hardware and software capabilities to the basic weapon system module. That is, with SIMNET-D the Army can simulate and evaluate a combat capability, including a new combat vehicle or vehicle subsystem, before having to build and field it. Once simulators have been reconfigured, the combat developer can evaluate the effects of the new capability on the performance of Army personnel and/or combat systems in simulated combat.

SIMNET Combat Vehicle Simulators

Two core design philosophies guided the development of the SIMNET combat vehicle simulators (Chung, Dickens, O'Toole, & Chaing, 1988). These philosophies are: (a) engineering first--the simulation should as much as possible model the behavior of the real system; and (b) selective fidelity--the simulation should represent the behavior of the system to the minimum level of detail required for users to perceive the system as realistic and acceptable. Currently, SIMNET simulators have been developed that represent tanks, infantry vehicles, air defense vehicles, and fixed and rotary-wing aircraft.

The SIMNET M1 Abrams tank simulators, for example, continuously update their operational status with respect to current battlefield conditions, such as ammunition loads, vehicle speed, grades being climbed, armor protection, equipment status, fuel capacity and fuel consumption. The tank module simulates the 105-mm main gun which is boresighted and zeroed, armed with HEAT and SABOT rounds, and linked to a stabilized laser range finder, gunner's primary sight, and to the commander's primary sight extension (Chung et al., 1988; U.S. Army Armor School, 1987). Figures 2 and 3 show the SIMNET M1 simulator turret and driver's area, respectively.

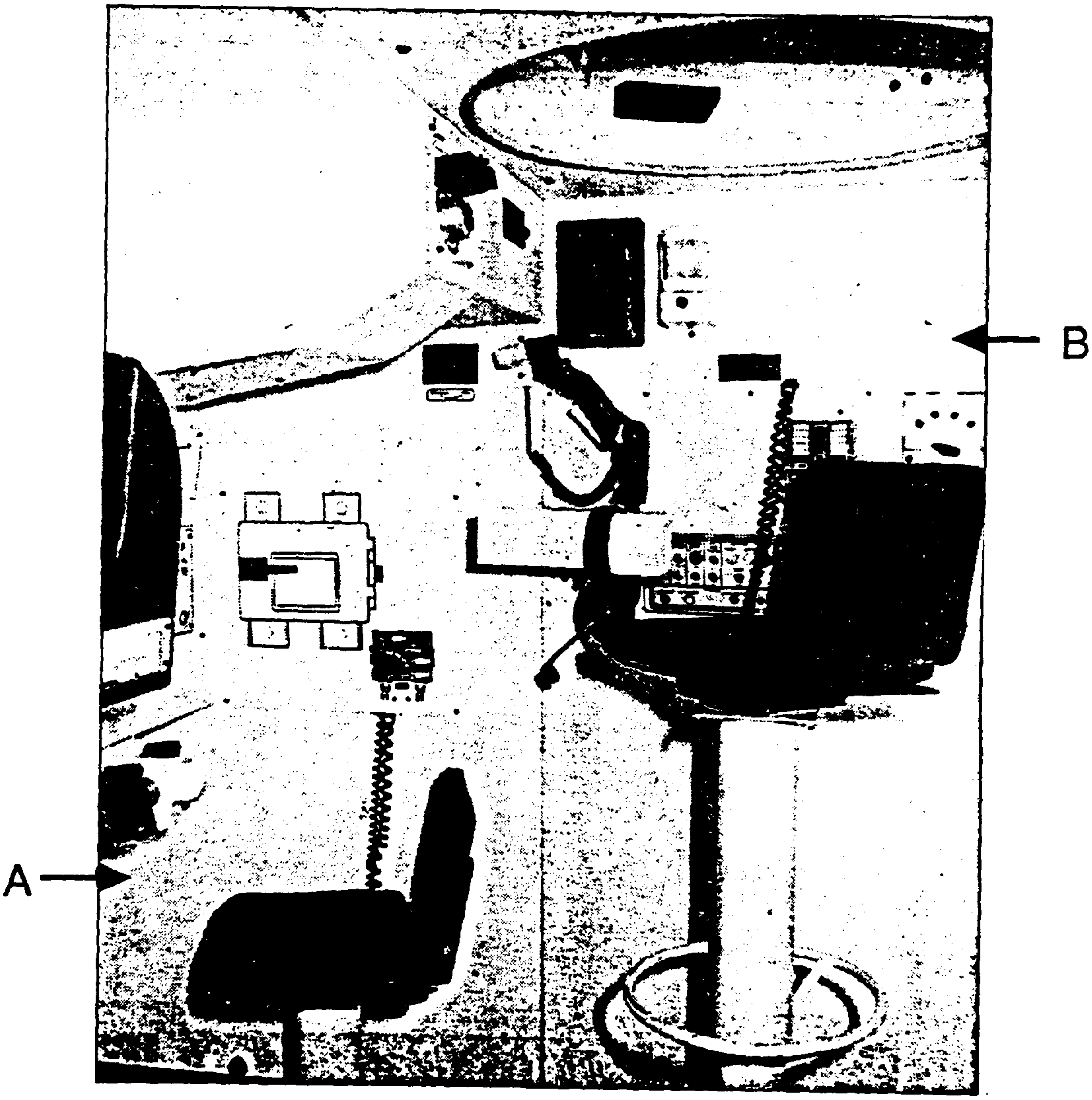

Figure 2. Crew compartment of the SIMNET M1 tank simulator, including (A) the gunner's station, and (B) the tank commander's station. The loader's station is not shown.

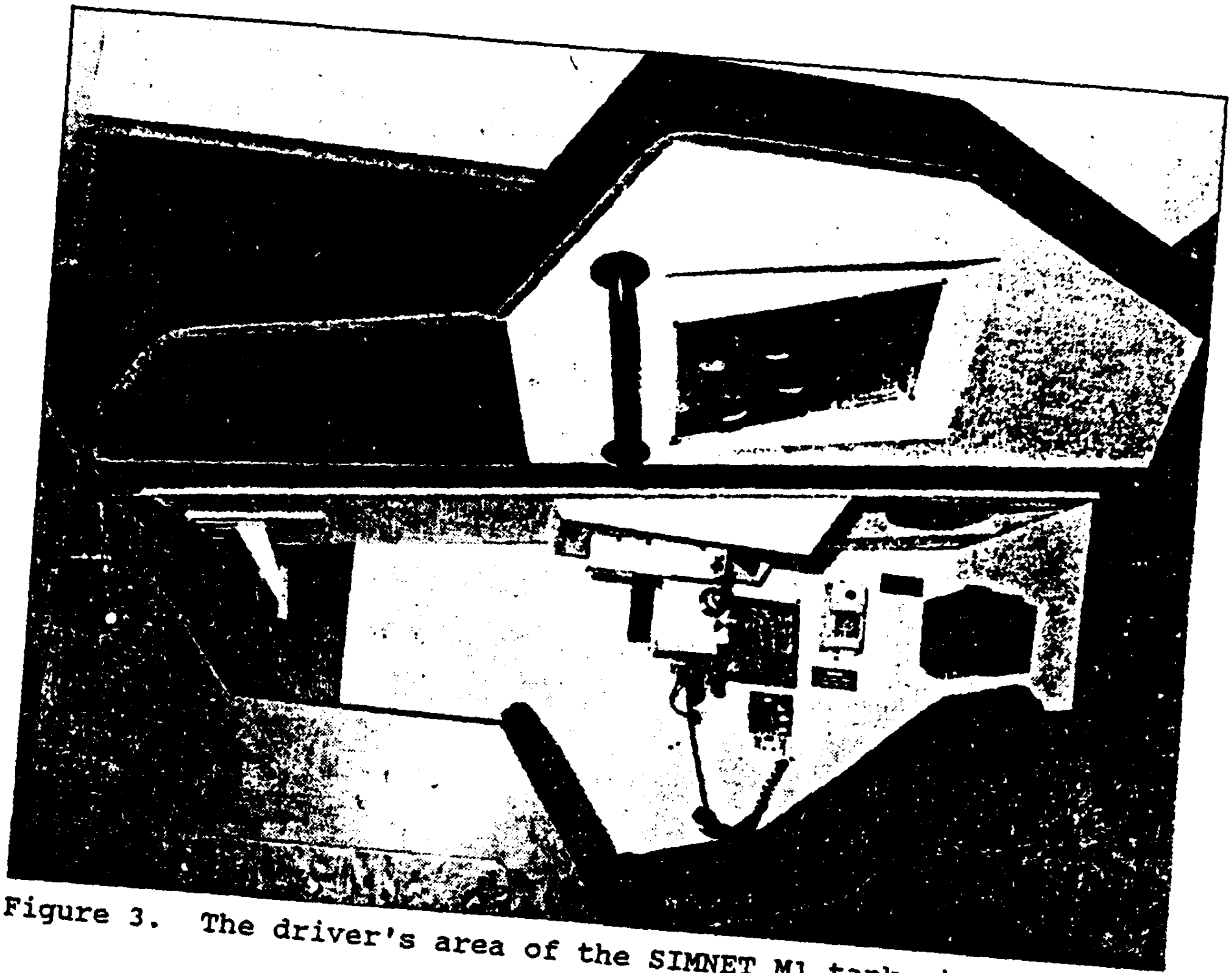

Figure 3. The driver's area of the SIMNET M1 tank simulator.

The SIMNET M1's visual system provides eight independent channels of computer-generated imagery, and these channels are divided among the four man crew. The vehicle commander, for example, is allotted three channels for one-power vision blocks mounted in a rotatable cupola, and shares with the gunner a repeater channel (three-power and 10-power) in the commander's main gun extension sight. The battlefield images generated provide crew members real-time (15 Hz) updates of the terrain features, other vehicles and weapon effects within a 3,500 meter radius while moving, scanning or shooting (Cyrus, 1987).

In addition, the SIMNET M1's sound system generates realistic battlefield acoustics, such as weapons firing and impacting, and vehicle sounds, such as engine whine and track movement, appropriate to tank speeds, terrain surface, steering and gear changes (Chung et al., 1988). The M1 simulation also incorporates a variety of stochastic failures (e.g., engine failures, thrown tracks) to model failures that occur on the real M1. For example, neither the real M1, nor the simulated M1, can climb a 60 degree or higher grade without throwing a track.

Consistent with a selective fidelity design, the SIMNET M1 simulators do not include some system components. For example, the M1's machine guns, thermal imaging system, and gunner's auxiliary sight are not represented. Similarly, display graphics can currently portray only a daylight environment. Hence, each researcher or trainer must evaluate the modules' fidelity to ensure the SIMNET environment suits their needs.

SIMNET-D Research Capabilities

In addition to the reconfigurability of the combat vehicle simulators, additional SIMNET research capabilities directly support the combat development test bed. These capabilities include the Semi-Automated Forces, Plan View Display, DataLogger, DataProbe, and RS/1. These research tools are shown in the expanded SIMNET-D distributive network in Figure 4.

An important feature of the SIMNET-D test bed is the Semi-Automated Forces (SAF) (Saffi, 1988a, 1988b). The SAF is a multi-vehicle simulation program which allows Army users and researchers to control automated, unmanned, opposing forces' (OPFOR) and friendly forces' (BLUEFOR) aircraft and vehicle systems. The SAF can save personnel and experimental resources that would be required to operate manned simulation modules.

Soviet doctrine, for example, dictates massive superiority of five-to-one or higher in any offensive operation. Without the SAF OPFOR simulation system, numerous enemy vehicle simulators and the soldiers to occupy them would be required to support SIMNET-D based tests. The BLUEFOR capability allows users and researchers to simulate friendly units for combat mission exercises. The placement and behavior (e.g., engagement range, firing accuracy, speed and direction) of OPFOR and BLUEFOR vehicles can be standardized for testing.

The SIMNET-D test bed includes the Plan View Display (PVD) monitor which provides an overview, in real-time or playback, of a SIMNET combat exercise as seen from "a bird's-eye view" above the simulated battlefield. The PVD depicts a color-coded digital terrain data base and provides the ability to selectively display various terrain features and details, including roads, rivers, and terrain relief. All combat vehicles in the SIMNET exercise, whether manned modules or semi-automated forces, are portrayed on the PVD.

The PVD can display other battlefield information, such as intervisibility status, designations of friendly and enemy tanks, and all movement and firing events (BBN Laboratories, 1986). It can replay combat exercises at various speeds, including fast forward. This feature allows review of a combat exercise in substantially less time than the actual exercise required. In addition, a flagging function allows exercise controllers to time-stamp selected exercise events for later analyses.

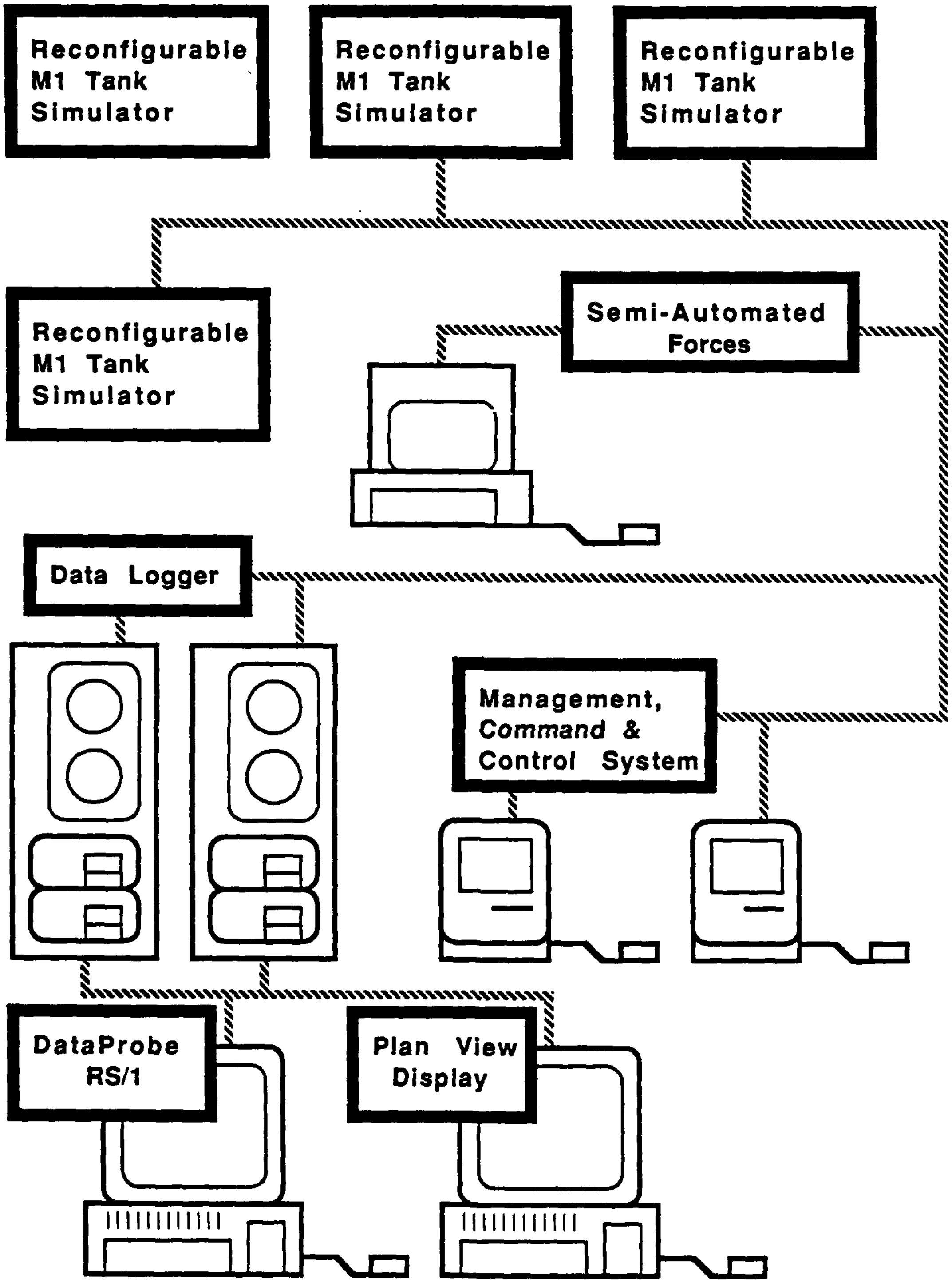

Figure 4. The expanded SIMNET-D distributive network.

Data Logger is a data collection system which captures and records all simulator network data traffic. The data which SIMNET produces are contained in "data packets." These packets are continually broadcast by each simulator and by the SIMNET Management, Command and Control System (MCC) at an estimated rate of 0.42/Kbytes/simulator/second (BBN Laboratories, 1986; Pope, Langevin, Lovero, & Tosswill, 1988).

Currently, SIMNET-D provides data packets containing information related to: (a) vehicle appearance (e.g., hull and turret orientation, grid location); (b) vehicle status (e.g., number of ammunition rounds available); (c) equipment status (e.g., equipment breakdowns); (d) vehicle firing events (e.g., location and type of round impacts); (e) indirect fire status (e.g., position of indirect fire impacts); (f) service requests and receipts (e.g., time of fuel, repair or supply requests or receipts); (g) vehicle collisions (e.g., tank collisions with other vehicles); and, (h) vehicle SIMNET activation status (e.g., vehicle initialization status--active or inactive) (Pope, 1988).

Data Logger can record and store any portion of the SIMNET-D data traffic for future playback or analysis. For example, the Data Logger allowed the current researchers to continuously record the actual grid locations for all tank simulator movements. These locations were later compared to the tank locations reported by all tank crews (e.g., checkpoint arrivals, own-location reports).

DataProbe[1] is a data management and analysis software package which accesses the Data Logger (Weinstein, Fortmann, & Moss, 1986). DataProbe includes a SIMNET Data Dictionary which defines and labels the various SIMNET-D data packets, and hence, facilitates the accurate isolation of selected portions of the Data Logger stored data that are of particular interest to Army researchers. Numerous mission, soldier, and interface effectiveness measures can be created using data collected by the Data Logger. DataProbe can produce descriptive statistics, color graphics or tables using the data stored by the Data Logger.

RS/1[2] is an interactive, programmable advanced statistics software package. RS/1 interfaces with DataProbe and allows researchers to perform a variety of data analyses, including linear and non-linear regression, parametric and non-parametric tests, and descriptive analyses (BBN Software Products Corporation, 1987). SIMNET-D data can also be recorded and

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[1] "DataProbe" is a registered trademark of BBN Laboratories Incorporated.

[2] "RS/1" is a registered trademark of BBN Software Products Corporation.

stored on magnetic tape for use with other computers and statistical software packages, such as the Statistical Package for the Social Sciences (SPSS/PC+)[3], Biomedical Data Programs (BMDP)[4], or the Statistical Analysis System (SAS)[5].

Limitations of SIMNET

Although SIMNET is a valuable research tool, users should be cognizant of at least three ways in which the SIMNET environment differs from the field setting. Each of these differences may have implications for the validity of SIMNET-D research for selected efforts, including the current POSNAV experiment. Unfortunately, research has not examined the relationship between soldier performance in SIMNET-D combat exercises and performance in similar field exercises.

First, tank commanders (TCs) frequently perform with the tank's hatch open during actual field exercises. Hence, commanders can move their heads out of the tank to directly view the entire battlefield and communicate with other units using arm and hand signals. The SIMNET tank modules, however, require TCs to operate in the closed-hatch, "buttoned up," mode. This problem is compounded by the nature of the commander's cupola in the SIMNET M1 simulator.

The SIMNET rotatable cupola only has three vision blocks or windows, allowing the TC only a 64-degree field of view at any one time. The M1 tank, however, provides commanders enough vision blocks to see an approximate 360-degree view of the battlefield. The inability to use arm and hand signals places constraints on the SIMNET commander's command, control, and communication (C^3) requirements, as well as navigation and target acquisition capabilities.

When operating with a closed-hatch, for example, platoon leaders often cannot see the other tanks in the platoon and must rely more heavily on radio communications for controlling and coordinating the actions of the platoon. The limited number of vision blocks makes it more difficult to determine the orientation of one's own tank, an important requirement for effective land navigation. One might think of SIMNET's battlefield conditions as those of a closed-hatch chemical weapons environment, an environment that will likely be prevalent in a future AirLand Battle (FM 100-5).

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[3]"SPSS/PC+" is a registered trademark of SPSS, Incorporated.

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[5]"SAS" is a registered trademark of SAS Institute.

Barron, Lutz, Degelo, Havens, Talley, Smith, and Walters (1976) compared the performance of tank crews and platoon in performing selected combat missions and functions with closed and open hatches. Twenty individual tank crews, four platoons, were assessed in their live fire performance of target acquisition, navigation, and C^3 tasks during both day and night exercises. Significant degradations in the ability to detect targets, move from point-to-point, negotiate obstacles, and maintain command and control were detected for both crews and platoons operating in the closed-hatch mode. No significant degradations in crew live fire, main-gun, hit performance or platoon fire distribution were detected.

A second difference between operating in the SIMNET versus a field environment has to do with the visual cues present in SIMNET computer image generation (CIG) graphics. Traditionally, field-based tank crews rely strongly on the sun, shadows, and object features for depth perception, orientation, and navigation. Current SIMNET CIG graphics do not simulate these orientation features.

The terrain depicted in the SIMNET world is also difficult to analyze. For example, it is often difficult to distinguish between hills in SIMNET. All hills tend to look alike. Moreover, forests in the SIMNET world are presented as a single line of penetrable fir trees, reducing opportunities for effective cover and concealment in SIMNET tactical maneuver.

In addition, the limited fidelity of SIMNET CIG graphics restricts the potential for identification and engagement of targets at ranges beyond 1,000 meters (Gound & Schwab, 1988). These target identification and engagement limitations have implications for some Armor combat mission tasks, such as reporting battlefield information (e.g., shell reports) and controlling platoon fires (e.g., issuing platoon fire commands).

Finally, the SIMNET CIG graphics software can only present a maximum viewing distance of 3,500 meters. Hence, the horizon as seen from the SIMNET tank modules' vision blocks and sights may or may not correspond with the actual battlefield horizon one would see from an actual tank in a field environment.

In response to the above differences, several compensatory strategies and tank simulator changes have been developed for SIMNET. For example, to compensate for SIMNET's closed hatch and limited visual fidelity, special paper maps were developed. These maps accurately portray all buildings, roads, hills, rivers, etc., as they appear on the simulated battlefield. Other compensatory modifications include a tank-based Grid Azimuth Indicator and Turret-to-Hull Reference Indicator, which partially compensate for the inability to use a hand-held compass and the lack of an open-hatch view of the hull and turret position.

SIMNET developers (e.g., Perceptronics, 1986a. 1986b, 1987) have also established some guidelines for soldiers operating in the simulators. For example, the maximum viewing distance of SIMNET allows an enemy force of any size, by any avenue of approach, to move within 3,500 meters of friendly forces before they can be detected. Hence, SIMNET developers urge TCs to deploy forces, including artillery and mortars, well forward along possible enemy avenues of approach. These are the same recommendations offered to Armor commanders operating in degraded visibility conditions (e.g., TCs conducting nuclear, biological, chemical (NBC), smoke, fog, or night operations). One should note, however, that experimental procedures could provide "intelligence" information about movements beyond the horizon.

Gound and Schwab (1988), as part of the SIMNET Concept Evaluation Program (CEP), noted the above limitations as the most significant. However, they also noted other less significant limitations of SIMNET which may affect the way soldiers perform. For example, the SIMNET tanks, unlike real tanks, lack battle markings or identification plates, making it more difficult for platoon leaders to identify and monitor their platoon tanks. Other limitations include the lack of appropriate tank crew position safety guards, the lack of a radio intercom accent capability, and the lack of a gunner's auxiliary sight.

In summary, differences between SIMNET and real tank battlefield conditions may argue against selected applications on SIMNET, despite the compensatory modifications and tactical recommendations previously noted. These differences must be analyzed carefully for potential effect on the performance, training, or doctrinal, issues in question. Even more importantly, before tank crews operate in SIMNET for training or testing purposes, they should be carefully instructed on these differences and compensatory strategies.

Advantages of SIMNET

Despite the limitations reviewed above, SIMNET offers some unique advantages over other tactical training and evaluation systems. In particular, SIMNET is a very good tool for assessing both C^3 and land navigation skills (Gound & Schwab, 1988; Schwab, 1987).

One of the advantages of SIMNET is the ability to readily place soldiers in realistic, task-loaded environments where combat mission tasks can be repeatedly assessed. In most combat gaming exercises, whether miniature model battlefields such as the Armor Combat Decisions Game developed by Baker and Cook (1962a) or computerized battlefields such as the Platoon Leader Battlefield Simulation (Kristiansen, 1987), tank crews do not face the high levels of battlefield stress and complexity achieved in SIMNET.

Moreover, board games and microcomputer simulations do not allow crews to practice many of the tactical mission behaviors across varying conditions that they can in SIMNET. In fact, SIMNET offers trainers and researchers the ability to allow soldiers to repeatedly complete tasks in realistic combat situations that are unsafe or are too expensive for field exercises, such as requesting indirect fires, reacting to air assaults, and bypassing enemy strongholds.

In SIMNET, tank crews can fight against other soldiers in a variety of combat simulators, including helicopters, tanks, jets and infantry vehicles. Unlike crews using combat games, tank crews in SIMNET do not use touch pads, remote control boxes, or flashlights to simulate mounted land navigation and gunnery (Baker & Cook, 1962b). SIMNET combatants can directly observe the effects of direct and indirect fire, and must perform critical mission tasks from within their tanks, often while in heated battle. They do not sit in chairs and peer at computers or "birds-eye" terrain models. They perceive the combat situation from the "inside-out" view. SIMNET combatants see the battle from inside their tank, as they would in the real tank on a real battlefield.

Communications are also more realistic in SIMNET. Jones, Wylie, Henriksen, Shriver, and Hannaman (1980) reviewed tactical board game trainers and noted that communication among soldiers in board games tends to be informal and conversational, and not representative of the radio communications required between unit or element leaders in a combat environment. In SIMNET, however, crews fight and communicate like they would in real tanks. They occupy their own vehicle and are physically prevented from directly observing or hearing other crews in their simulators. They use an intercom for communications within each tank and communicate with other tanks by selecting preset frequencies for platoon, company and other radio networks.

Another important feature of SIMNET-D is the ability to record and analyze large quantities of diverse data including mission, soldier, and soldier-machine-interface effectiveness measures. SIMNET-D provides an opportunity to evaluate some mission tasks which, by their nature, cannot be easily or effectively assessed in field combat mission settings, such as the accuracy of spot reports, shell reports, and calls for fire.

Moreover, ancillary measures can be assessed using the playback and analysis features of the PVD. Subject matter experts (SMEs) can be presented with standardized recordings (e.g., identical audio and PVD-based video recordings) of combat missions to evaluate. These SMEs can be "blind" to any experimental treatments or issues which guide the evaluations.

Previous SIMNET Research

Thus far, only a few assessments have been completed using SIMNET resources. A Proof of Principle Project (Schwab, 1986) conducted by the Armor Test Division of the U.S. Army Armor and Engineer Board (AEB), the first SIMNET-based evaluation, specifically addressed two critical issues:

1. Does the SIMNET system have the potential to be a combat development simulator?

2. Does SIMNET have the potential to reduce test resource requirements and enhance the data reduction process?

A vehicle navigation aid (NAVAID) was integrated into eight SIMNET M1 simulators to test these issues. This navigational capability was integrated solely to demonstrate the testing and analysis capability and adaptability of SIMNET technology. Unlike the objective of the present research, the AEB Proof of Principle Project was purely a demonstration of SIMNET-D's capability to be a combat development analysis tool, not an evaluation of alternative navigational system display formats and their effect on tank crew and platoon performance (Schwab, 1987).

Furthermore, the NAVAID system used in the AEB assessment presented tank commanders with only stand-alone digital readouts of Universal Transverse Mercator (UTM) military grid coordinates and vehicle heading data, whereas the POSNAV system evaluated in the present research integrated this critical navigation-related data with an analog map or grid matrix display. There are significant differences, as well, in the NAVAID driver's display used in the AEB Proof of Principle project and the POSNAV driver's display used in the present experiment.

In the NAVAID study, two tank platoons completed a variety of tank crew and platoon combat drills and exercises with and without the NAVAID capabilities. The Data Logger, DataProbe, RS/1 (with BMDP) and the PVD were used for all data collection and analyses. Semi-Automated Forces were used to simulate enemy forces. While data were collected on tank crew and platoon performance in the combat exercises relative to NAVAID, the primary measures evaluated were related to the performance of the SIMNET data collection and analyses capabilities.

Generally, the data from the AEB Proof of Principle Project provide evidence that SIMNET technology can be successfully used for combat development research. Specifically, the AEB found that the tank simulators could be quickly modified with the NAVAID system and that the SIMNET-D tools (i.e, PVD, Data Logger, DataProbe, RS/1) could be used effectively to monitor, record, control, and analyze the actions of crews and platoons in the simulators. Schwab (1987) estimates the SIMNET-based experiment saved more than $30,000 over what a similar contractor field test would have cost. Hence, SIMNET appears to have the ability to both reduce test resource requirements and facilitate the data collection and analysis process.

Nevertheless, the AEB and BBN (the NAVAID system developer) voiced some concerns relative to using the SIMNET technology for evaluating combat developments (Huggins, 1986; Schwab, 1987; Schwab, personal communication, 1987). These concerns focus primarily on the conduct of a combat development investigation.

First, the AEB and BBN stressed the need for combat development researchers to conduct effective familiarization training for soldiers preparing to use the combat capability under evaluation. A four-hour training program developed by the AEB proved ineffective for appropriately orienting soldiers to both the SIMNET and NAVAID systems (Schwab, personal communication, 1987). Schwab suggests at least a full-day be dedicated to orienting soldiers to SIMNET and the new combat capability being evaluated. This training should include "shakedown" exercises that give soldiers opportunities to actually practice using the capability before any actual testing begins. Researchers should be certain that the combat crewmen know how, when, and why to use a new combat technology during an experiment. Moreover, researchers should allow for and encourage creative uses of the new combat equipment by the soldiers.

Another problem noted by the AEB and BBN which is relevant to evaluating soldier-machine-interface requirements is that the performance measurement and, particularly, exercise event flagging should be carefully controlled by test administrators. In the AEB evaluation, tank crews and platoons indicated their arrival at a checkpoint by pressing a **WAYPOINT REACHED** key on the prototype NAVAID display. However, several commanders inaccurately or repeatedly pressed the key, resulting in unreliable waypoint arrival time and accuracy data. Researchers should monitor and record exercise events as fully as possible, using a test administrator log and the PVD-based event flagging function whenever possible.

Third, the AEB and BBN found that many tank crews and platoons were unable to complete some of the individual combat exercises in the time allotted, resulting in missing performance data. Although it can be expected that some crews may not complete each tactical exercise, this problem may have been reduced through pilot studies. Future research efforts should conduct pilot studies. These studies are important for determining the amount of time required for most crews to complete each combat exercise and for evaluating event flagging, data collection, and training and testing administration procedures. Testing procedures should be developed to ensure that performance data on all critical mission elements can be collected. This may involve initializing crews at their next objective or waypoint after they become lost or are destroyed by enemy fire.

Finally, the AEB and BBN found a serious problem in using taped voice radio communications from the tank simulators. Data analysts discovered upon completion of the experiment that the radio traffic and the data packets captured by the Data Logger were not appropriately synchronized with respect to time. This lack of radio synchronization required the researchers to attempt an approximate synchronization of the data. Hence, researchers evaluating voice radio traffic on SIMNET are urged to devote special care in pilot tests before actual SIMNET testing takes place to ensure that voice radio traffic and the SIMNET data packet network are appropriately time synchronized.

A follow-up AEB SIMNET CEP (Gound & Schwab, 1988) evaluated the operation, training, and evaluation utility of SIMNET from the user's viewpoint. Overall, the majority of users asserted that SIMNET was useful in training tactical command and control (C^2) and maneuver skills, even though a number of deficiencies in simulator operations (described earlier) were noted. An important product of this CEP is a series of tables which list platoon-level mission tasks which the authors and users believed could be fully, partially, or not trained and evaluated in SIMNET. These tables were guides for defining the domain of tasks included in the current SIMNET-based evaluation.

The U.S. Army Air Defense Artillery (ADA) Board also recently completed a SIMNET-D demonstration/evaluation of a prototype Forward Area Air Defense Systems (FAADS), a combat weapon system capable of acquiring and engaging enemy aircraft (Pate, Lewis, & Wolf, 1988). The objective of the FAADS test was to determine if SIMNET-D offers technology for addressing critical air defense force development testing and experimentation (FDTE) and initial operational test and evaluation (IOTE) issues. Overall, the FAADS test objective was successfully met.

Kraemer and Bessemer (1987) investigated the conduct and effects of SIMNET training for the 1987 Canadian Army Trophy (CAT) competition. Their findings suggested that SIMNET training may have helped the U.S. CAT team develop and improve their fire control distribution plans and helped unit leaders develop the C^3 skills to effectively execute those plans during platoon battle runs.

The Position Navigation (POSNAV) System

Subsystem Integration

While the present research is concerned only with evaluating the POSNAV system, POSNAV is not intended to be a stand-alone system. As noted earlier, POSNAV and IVIS are expected to be integrated in the future tank. Commanders will access POSNAV information and functions through the IVIS interface.

IVIS is a computer-based distributed command, control, and communication device. It is designed to assist in the synchronization of the force by helping commanders, at the vehicle-level and above, to effectively coordinate mission planning and execution by providing the most accurate and timely information possible (Blasche & Lickteig, 1984; Polk & Lee, 1987). While the POSNAV system will give TCs access to automated navigational information, IVIS will provide TCs with automated tools to evaluate battlefield conditions, determine target locations, evaluate unit supply status, determine battlefield intervisibility, and rapidly prepare, transmit, and receive battlefield reports.

Presumably, IVIS will speed up the decision cycle of commanders, while also insuring that everyone has the same view of the battlefield. IVIS is expected to substantially improve the Army's current communications and information management system which is largely based on voice radio, a system "hardpressed...(and) hampered...by sluggish information processing and...handling" (Polk & Lee, 1987, p. 26). For more detailed descriptions of the problems in the Army's current voice radio communications, see Phelps and Kupet (1984) and Coleman, Stewart, and Wotten (1986).

Even though the U.S. Army has not completely decided on the specific functions IVIS will perform or which combat vehicles will incorporate IVIS, Army researchers have considered possible IVIS user interface designs (Lickteig, 1986; Lickteig, 1988), information requirements (Blasche & Lickteig, 1984; Jobe, 1986), training implications (Lickteig, 1987), and data transmission requirements (Polk & Lee, 1987).

The POSNAV System

While SIMNET-D-based research in progress is evaluating IVIS, only those capabilities relevant to the operation of the Position Navigation (POSNAV) system were operational and evaluated in the present research. These capabilities included:

1. Analog spatial map display and own-vehicle icon
2. Own-tank location and heading window
3. Map features function
4. Map zoom function
5. Map scroll function
6. Route designation function
7. Driver's steer-to information display

A primary feature of the POSNAV system is its ability to link critical navigational data such as own location and heading information to the map display area, which displays the immediate area surrounding one's own tank. One's own tank is represented by an icon.

Depending on the POSNAV display condition to which an experimental tank crew or platoon was assigned in this research, the map display area showed either a UTM grid matrix map or a terrain map. The grid matrix display, shown in Figure 5, represents the display currently anticipated with the first fielded generation of IVIS and is referred to in the current research as POSNAV-Grid or POSNAV-G. The terrain map display, shown in Figure 6, represents the more advanced display expected with later generations of IVIS and is referred to as POSNAV-Terrain or POSNAV-T.

The own-vehicle grid location and heading window, located on the lower right corner of the map display area, shows current own-tank location as an eight digit grid and the current own-tank compass heading in mils. As the simulated tank moves, this information is updated and displayed in the POSNAV display window. This information supplements the graphic indication of own-tank location and heading provided by the location and orientation of one's own tank icon on the POSNAV-G and -T map displays.

The majority of the report and menu keys presented on the POSNAV interfaces evaluated in this experiment are part of IVIS and were not operational during this research. Two menu keys, the **MAP** key and the **NAV** key, however, were operational.

The **MAP** key provides the tank commander with access to three functions for manipulating the map display area. These functions include a "map features", "map zoom", and "map scroll" function. Commanders can access these functions from the **MAP** main menu by pressing the **MAP** key. These functions allow tank commanders to adjust their map to best suit the task at hand. Once activated, the **MAP** and **NAV** key main menus and submenus appear in the variable menu area on the right side of the POSNAV interface.

The "map features" function distinguishes between display formats evaluated in the current experiment. The terrain map of the POSNAV-T display format is modified by the "map features" function. This function allows the POSNAV-T commanders to add or subtract color-coded terrain features (e.g., roads, grid lines, river, buildings, vegetation, and contour intervals) on the map display area.

The POSNAV-G display format, which includes only a grid map, does not incorporate the features function. The grid map can only portray UTM grid lines. The prototype display could be initialized by test controllers as either a POSNAV-G or -T display simply by turning the "map features" function off or on, respectively.

The "map zoom" function allows commanders to adjust the scale of the map display. Commanders can use a 1:25,000 scale, 1:50,000 scale, or 1:125,000 scale map. Commanders can change map scales at any time.

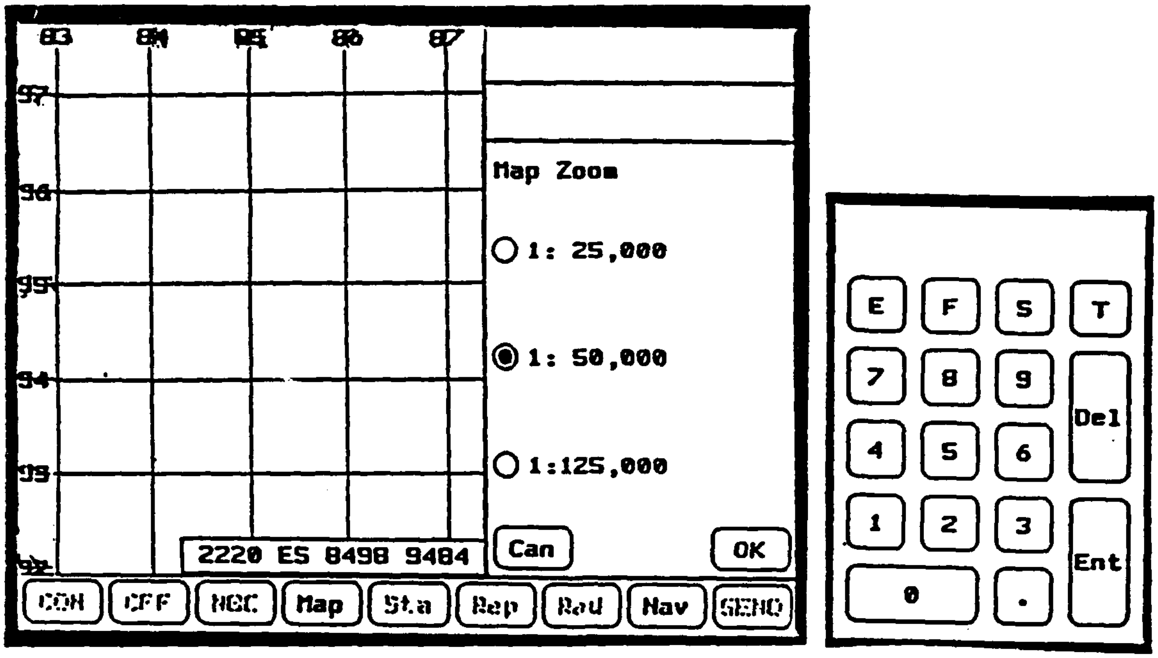

Figure 5. POSNAV tank commander user interface with grid display (POSNAV-G).

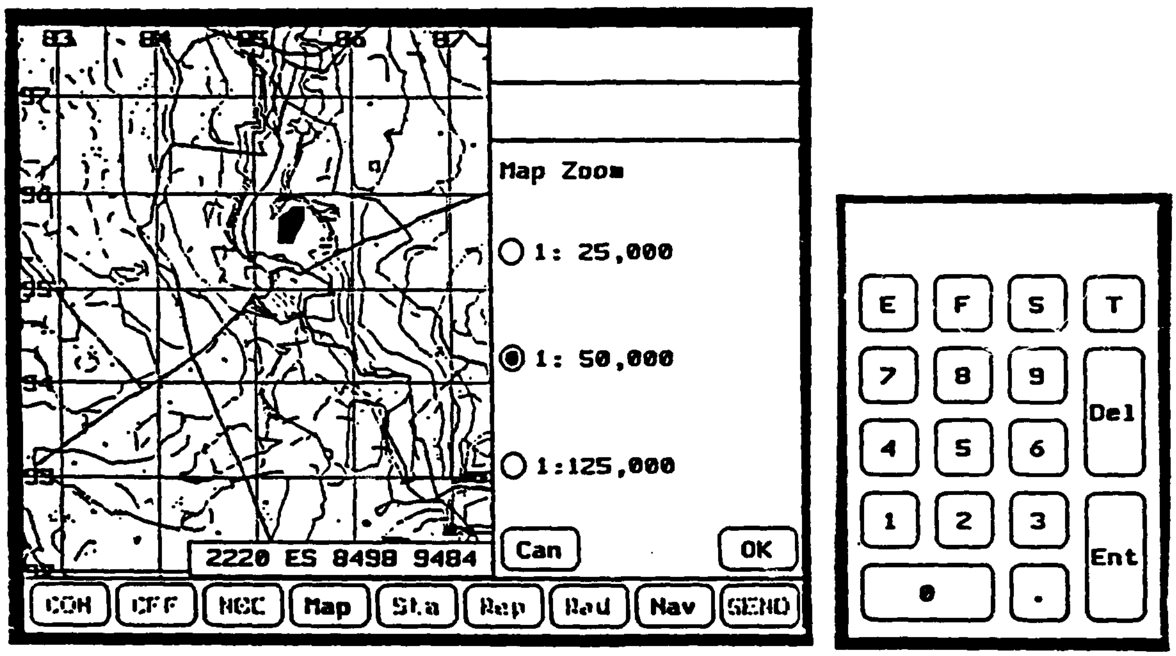

Figure 6. POSNAV tank commander user interface with terrain display (POSNAV-T)

The "map scroll" function allows commanders to change the area portrayed on the map display. A tank commander can either center his own tank on the map (the default) or center a grid coordinate of his choice, such as a specific checkpoint.

The **NAV** key provides the tank commander access to a route entry and navigational management function, the "route designation" function. The "route designation" menu, accessed by pressing the **NAV** key, is presented in Figure 7. This function, specifically designed to support land navigation, allows tank commanders to enter grid coordinates for their mission or road march route into the POSNAV device so the route is displayed on the map display. Grid coordinates are entered by the TCs using a digital keypad located to the right of the commander's POSNAV display. After a route is specified, the POSNAV system monitors route progress and updates the vehicle icon's location and orientation along the route designated.

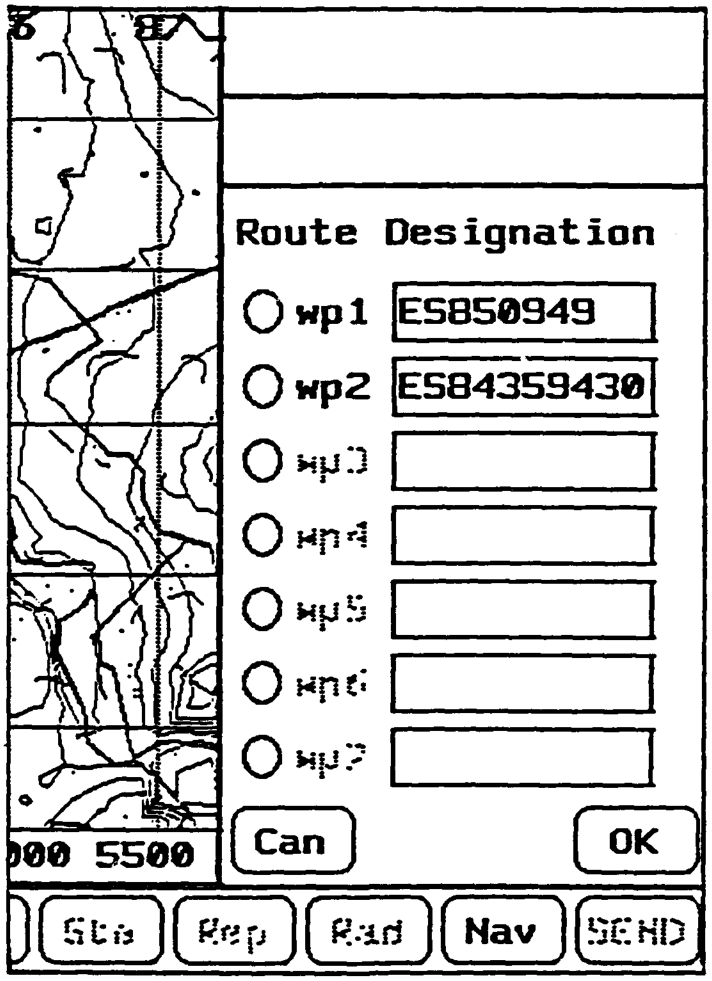

Figure 7. The POSNAV system **NAV** route designation menu.

The POSNAV device also provides tank drivers with important route progress information. This information is displayed on the driver's "Steer-to" display, shown in Figure 8, and includes:

1. The number of the waypoint currently displayed.
2. Current own-vehicle distance from the next route waypoint (in kilometers).
3. Current own-vehicle azimuth heading (in mils).
4. Current own-vehicle azimuth heading required to reach the next waypoint (in mils).
5. A steer-to indicator which shows the direction one should steer the vehicle to reach the next waypoint.

The clock-pattern structure of the driver's "Steer-to" display used in this experiment is significantly different from the two arrow indicator used in the AEB Proof of Principle project described earlier (Schwab, 1987). In the current research, the "Steer-to" type of driver display was used for both the POSNAV-G and -T display conditions.

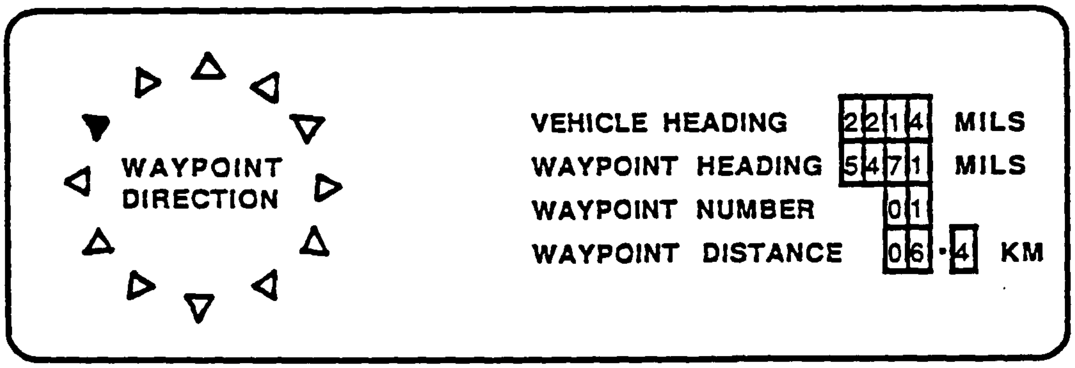

Figure 8. The driver's display used in the POSNAV-G and POSNAV-T test condition.

Tank Crew/Platoon Performance

Task Analyses and Limitations

The first step in developing exercises and measures for evaluating tank crew and platoon performance is to identify the domain of tank crew and platoon task and mission objectives. Fortunately, descriptions of tank crew/platoon tasks and missions are available in numerous U.S. Army publications (e.g., Army Training and Evaluation Program (ARTEP) 71-2, FM 17-12-1, ARTEP 17-237-10-Military Training Plan (MTP), FM 71-1, Field Circular (FC) 17-15; FC 17-15-1, FM 21-26, Soldier Training Publication (STP) 17-19K24, STP 17-19K1), and research reports (e.g., O'Brien & Drucker, 1981).

Currently, the Army Training and Evaluation Program for Mechanized Infantry/Tank Task Force (ARTEP 71-2) serves as the encyclopedia of all tank crew/platoon mission tasks, conditions, and standards. ARTEP 71-2 serves as the measure against which the performance of all Army tank crews, platoons, and companies is evaluated.

Other U.S. Army Armor Center (USAARMC) reports serve as companion reports for ARTEP 71-2. FC 17-15, FM 71-1, and ARTEP 17-237-10-MTP, for example, serve as the "how to" manuals for company commanders to develop tactical exercises for use in preparing their tank crews and platoons for ARTEP performance evaluations. Fort Knox Skills Manual (FKSM) 17-1, FM 17-12-1, and FM 21-26 also complement ARTEP 71-2 by expanding on tank crew and platoon combat orders and plans, gunnery, and land navigation, respectively. The U.S. Army Armor School Master CMF 19/SC 12 Task List, as well as STP 17-19K24 and STP 17-19K1, are updated frequently and provide lists of tasks for individual tank personnel.

Army researchers have developed similar classifications and descriptions of tank crew and platoon tasks, task conditions, and standards. For example, O'Brien and Drucker (1981) analyzed Armor operations to identify, classify, and interrelate the activities/tasks performed during all tank platoon missions. Their six-volume report contains training objectives for tank crew and platoon tasks, Armor operation time sequences, platoon leader task descriptions, and outlines showing the relationships among collective and individual tasks in tank platoon operations.

Historically, these Army manuals and research reports have served as the basis for the development of tactical scenarios, exercises, and test items used in research to evaluate or construct measures of tank crew/platoon effectiveness (e.g., Bessemer, 1985; Gound & Schwab, 1988; Schwab, 1987). These sources, however, are not without limitations.

First, several of the task conditions and standards outlined in ARTEP 71-2 and other crew and platoon task analyses are not objectively defined. This is especially true with tasks conducted in a tactical setting. For example, evaluating platoon objectives like "Control Techniques of Movement" or "Understand Commander's Intent" requires considerable ingenuity and effort to systematically cue and reliably measure.

Second, it is difficult to accurately specify the complete nature of the tank crew or platoon's job. While several different task analyses have been completed, few analysts have agreed on which tasks and, more particularly, which standards apply to tank crews and platoons.

Third, while ARTEP 71-2 and other Army publications may specify certain standards for each tank crew and platoon task, these standards may or may not be fully applied in the field.

For example, tank crews and platoons are required to report battlefield information in a precise format, the S-A-L-U-T-E (i.e., size-activity-location-unit-time-equipment) format. Depending on the unit a tank crew or platoon is in, etc., however, battlefield reports may be accepted with less rigid standards.

Fourth, the same crew and platoon tasks can occur in a number of different mission contexts and under a variety of conditions. A complete test covering all possible contexts and conditions within even a small crew or platoon task domain could be unacceptably long given applied research constraints. Hence, efforts must be directed to sampling enough critical task conditions to reliably assess crew and platoon performance while maintaining a practical test length. Wheaton and Fingerman (1978) illustrate an approach to sampling tasks and conditions in the development of a simulation-based criterion-referenced test of tank gunnery.

A final limitation of current crew and platoon task analyses is that current military standards for performance are often vague, subjective, or unspecified. For example, the MTP 17-237-10 lists four standards for "Collect and report tactical information", a task involving determining and reporting enemy locations and activity. These performance standards include:

1. Personnel observing subject to be reported used the key word S-A-L-U-T-E to collect essential information.

2. Observer organizes information into spot report format prior to sending transmission (writes down grid and time).

3. The observer sends the spot report in at least two transmissions.

4. The observer updates the spot report as the situation changes (pp. 5-26 and 5-27).

These standards are scored on a Go/No Go basis. However, exactly what is an adequate update rate for spot reports or the relative importance of each of these performance standards are not indicated.

Overall, while the identification of tasks for the current effort was heavily influenced by the various Army task analyses previously cited, this guidance was not accepted without question. Current efforts were directed at not only interpreting but--in some cases--specifying with SME guidance appropriate tasks, subtasks, conditions, and performance standards for the Armor crew and platoon jobs.

Developing Test Exercises

Some Army researchers have offered guidance and provided research tools for preparing tactical exercises at the crew and platoon level. Henriksen, Jones, Sergent, and Rutherford (1985) utilized the literature on tank crew and platoon tasks and missions to define and conceptualize media and device combinations that have potential to support effective training on tactical leadership tasks for Armor platoon leaders. Of special interest to the present research are the procedures outlined for tactical exercise development.

Henriksen et al. (1985) first focused on reviewing Armor publications and other reports presenting tank crew and platoon tasks for scenario development related to their hypotheses. Next, the researchers wrote rough draft exercise outlines to reflect those tasks related to their hypotheses for scenario development. A series of refinements to these rough outlines, based on a consideration of factors such as battlefield terrain features, pilot evaluations, and subject matter expert guidance, led to the development of final scenario outlines. At this point, the scenarios were written in a format which specified prevailing conditions, visual/audio cues, a timeline, tank commander/platoon leader responses, and background information. An attempt was made to include all critical actions required by the platoon leader during each scenario and to make technical details as accurate and realistic as possible.

Bessemer (1985) used a similar procedure for developing four tactical scenarios to evaluate the TRAX-1 gaming method for tank platoon tactical training. Henriksen's procedures for developing tactical exercises served as a model for the current effort to build upon.

Wheaton, Allen, Johnson, Drucker, Ford, and Campbell (1980) also present valuable information regarding the development of objective, relevant measures of tank platoon battle run performance. An important product of their research is a series of tables which list the criteria constructs for evaluating defensive and offensive platoon mission objectives along with suggested measurement procedures and standards for scoring platoon performance on these constructs. Many of these constructs expand upon current ARTEP standards which facilitated more complete, objective crew and platoon measurement in the current experiment.

Wheaton's analyses also illustrate a serious problem which occurs in the Army's current crew and platoon performance evaluation procedures. Frequently, observers will be posted along a mission route and/or on-tank to evaluate the performance of Armor crews or platoons. However, these observers are often faced with insufficient observational opportunities to effectively evaluate crew and platoon performance. A structured testing approach, along with the SIMNET-D resources available for performance measurement and on-board data collectors, allowed the current research effort to improve the fidelity and objectivity of platoon performance assessments.

Especially relevant to the current SIMNET-D-based experiment are three DARPA reports which describe general requirements and guidelines for developing tactical exercises on SIMNET (Perceptronics, 1986a, 1986b, 1987). While these manuals are directed toward preparing Armor and Infantry commanders for running SIMNET-T-based training exercises, not SIMNET-D experiments, some valuable information is contained in these reports. For example, these reports describe simulator initialization, combat service support, and other exercise-management procedures.

The AEB experiments (Gound & Schwab, 1988; Schwab, 1987) described earlier also provide examples of the development of tactical exercises and measures of effectiveness for evaluating tank crew and platoon performance on SIMNET. Schwab (1987) developed tactical exercises and criteria for evaluating the effect of a navigational system on tank crew and platoon effectiveness. Gound and Schwab (1988) also developed platoon tactical exercises to evaluate the training capabilities of the SIMNET system. These measures and exercises, including their associated overlays and combat orders, served as valuable resources in the development of the test exercises and measures used in this research, as described in the method section.

Statement of the Research Problem

In summary, the problem addressed in this research involves conducting an evaluation of a SIMNET-D prototype POSNAV system. The purpose of this research was to investigate the effect of alternative POSNAV information display formats on soldier performance. Tank crew and platoon performance with POSNAV were compared with the performance of crews and platoons in a control group, no POSNAV, which used only the navigational tools and procedures currently available.

Selection of the alternative POSNAV display formats was guided by the POSNAV proponent's (USAARMC's) expectations regarding the system's potential operating characteristics. Hence, the two POSNAV display formats evaluated represent (a) the display format anticipated for the near-term POSNAV system, POSNAV-G or grid map display; and, (b) the display format anticipated for later generations of POSNAV, POSNAV-T or terrain map display. The only difference between the alternative formats is the addition of terrain features to supplement the grid matrix map display.

The current evaluation, using SIMNET-D M1 modules, resources, and IVIS prototypes, provides an opportunity to evaluate the performance effects associated with the POSNAV developmental system before it is actually built and fielded. Despite some of its limitations, SIMNET-D offers several advantages over other tactical training and evaluation tools. In addition, this experiment provides user perceptions, as well as training implications, of both the currently anticipated grid map display format and the terrain map display format envisioned for the future POSNAV system.

Method

Conditions

The three conditions of this experiment are described below:

1. Control Condition (POSNAV-C). In the control or baseline condition, tank crews and platoons conducted road march and combat mission exercises without the aid of a POSNAV system. Hence, navigation was accomplished using conventional navigational aids and the SIMNET assets provided to help with simulation-based navigation. These aids include the use of a paper map, the field of view from the tank's vision blocks and sights, an azimuth indicator, and radio network communications with other crew and platoon participants.

2. POSNAV-G (Grid Matrix Map Display with Tank Icon). In addition to the navigation aids available in the control condition, the tank crews and platoons in this condition were equipped with the POSNAV system. The display available to the TCs in this condition presented a map limited to a UTM labeled grid matrix and a tank icon representing own-tank position and hull and turret orientation. Location and heading information was indicated digitally, without error, in an "own location and heading window" on the POSNAV display. The touch sensitive display housed two operational menu keys, the **MAP** and **NAV** keys, which provided tank commanders with access to the "map zoom," "map scale," and "route designation" functions. A driver's display, showing movement progress information, was also available. Figures 5 and 8 (presented earlier) illustrate the POSNAV-G tank commander's and driver's display formats, respectively.

3. POSNAV-T (Terrain Map Display with Tank Icon). In this condition, all tank crews and platoons used the navigational aids available in both the control and POSNAV-G conditions. The POSNAV display in this condition, however, included the capability to overlay critical terrain features, including contour lines, roads, vegetation, water, and buildings, onto the grid matrix map display (see Figure 6). The tank commander also had access to one additional **MAP** function, the

"map features" function. This function allowed the commander to customize the POSNAV map with any combination of available terrain features. The map terrain feature is what distinguishes the POSNAV-G and POSNAV-T display formats.

Hypotheses

Below are the research hypotheses which were tested in the present experiment:

1. Crews equipped with the POSNAV system (POSNAV-G and POSNAV-T) will perform significantly better on road march exercises than crews in the baseline condition, POSNAV-C, without POSNAV.

2. Platoons equipped with the POSNAV system (POSNAV-G and POSNAV-T) will perform significantly better on tactical mission exercises than platoons in the baseline condition, POSNAV-C, without POSNAV.

The evaluation of both the grid and terrain POSNAV map display formats is exploratory and based on anticipated POSNAV improvements. Hence, no hypotheses were presented regarding crew and platoon performance differences between these formats.

Apparatus

Throughout this research, a variety of materials were used. These materials included four SIMNET-D M1 tank modules equipped with POSNAV. The nine-inch diagonal POSNAV display was represented on a high-resolution (1280 pixels by 1024 lines) 19V inch 100 MHz Taxan color monitor with 0.31mm dot pitch. The POSNAV TC's display was mounted in the right front area of the M1 modules commander's area, the location currently anticipated for the fielded POSNAV display. Figure 9 shows the location of the POSNAV interface in the SIMNET M1 commander's station. The driver's display was mounted above and to the right of the driver's T-bar, or steering column. Figure 10 shows the location of the POSNAV driver's display in the SIMNET M1 driver's station. The POSNAV displays were inactive during control group testing. The SIMNET-D research capabilities previously described, including the SAF, PVD, Data Logger, DataProbe, and RS/1, were also used for data collection and analysis. A classroom in the SIMNET-D building was used for familiarization training of crews and platoons, as well as for all debriefing sessions. Training sessions incorporated the use of an overhead projector and video cassette player.

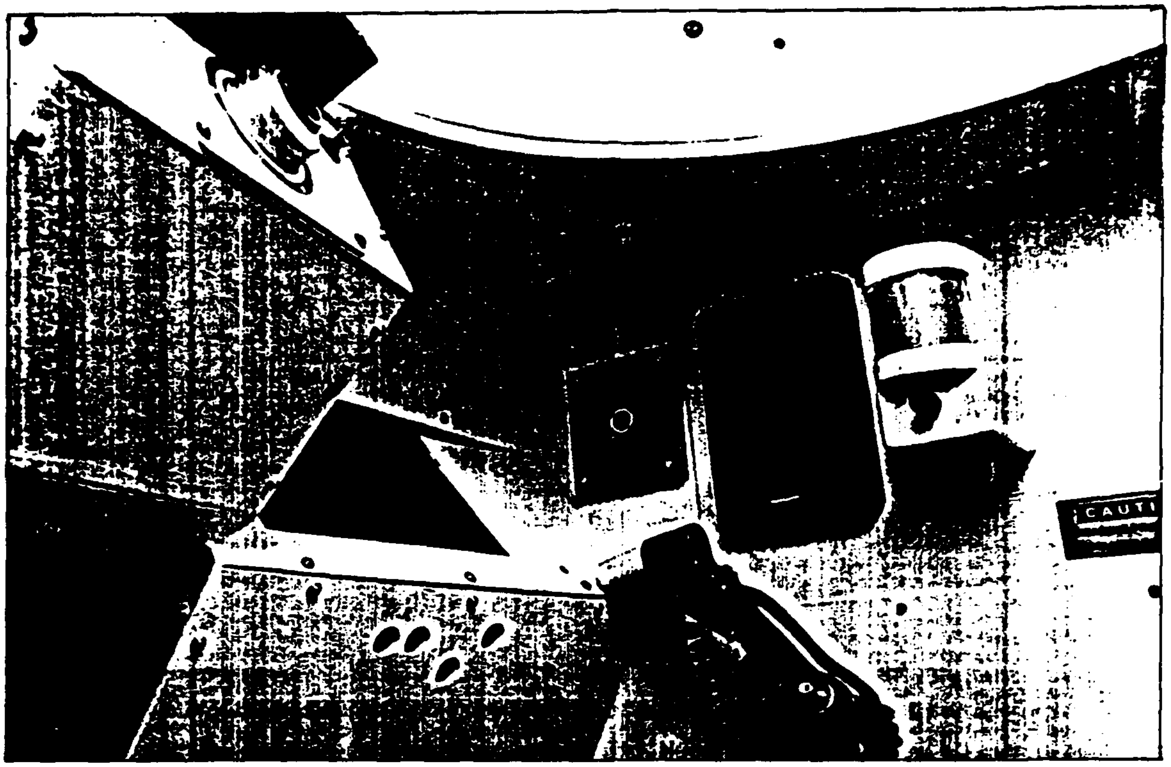

Figure 9. The TC's POSNAV display mounted in the SIMNET M1 commander's weapon station.

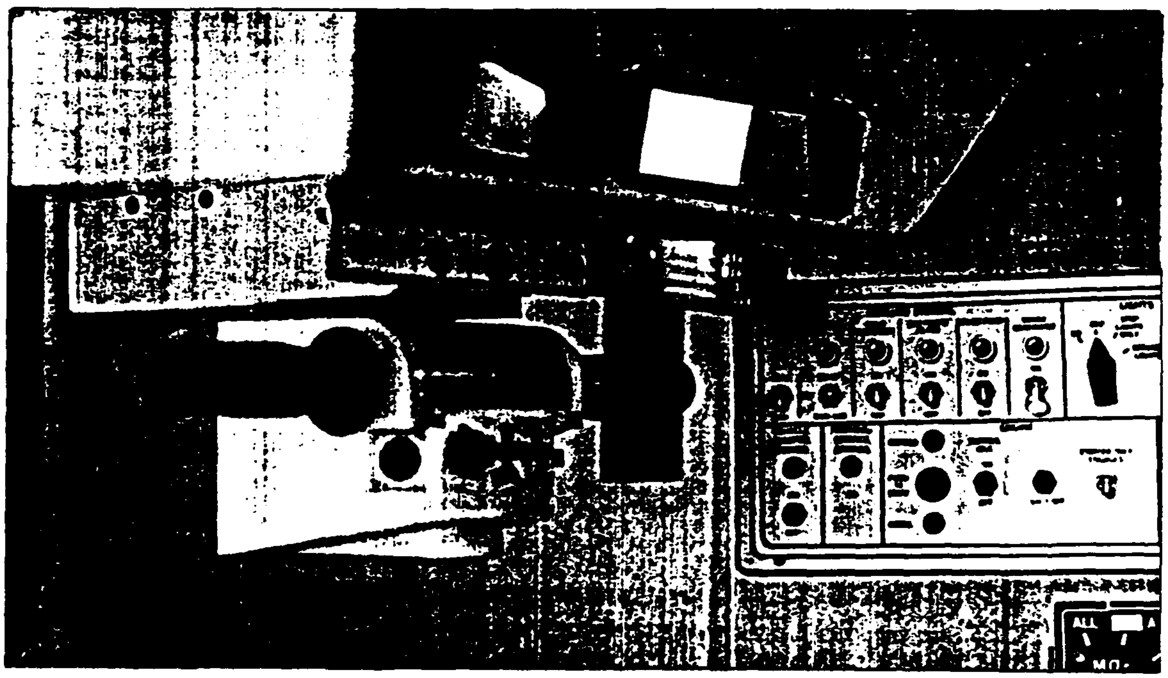

Figure 10. The driver's POSNAV display mounted in the SIMNET M1 driver's station.

Design

This experiment evaluated tank crew and platoon performance across three levels of one independent variable: navigation condition. In choosing an among-groups design, the advantages and limitations of both the within and among-groups designs were carefully considered.

Ultimately, situational constraints were the major influence on the decision to use an among-groups design. The primary constraint was the limited number of tank platoons available to participate in this experiment. Only about half of about 28 Armor platoons stationed at Fort Knox, Kentucky, were expected to be available to participate in the current evaluation.

Additional constraints included the limited time available for training and testing each platoon as well as the availability of the SIMNET-D M1 tank modules and other resources. For example, while a within-groups design was favored because of its greater statistical power with small sample sizes, time restrictions for subject participation and SIMNET-D availability favored an among-groups design. The very real possibility of differential "carry over" effects from one test condition to another was also a concern with the within-groups design.

Numerous test design options, varying on sample size and time required, were outlined for review (see Blunt, Du Bois, & Motola, 1987). After a consideration of the advantages and disadvantages of each design, in light of the practical constraints discussed above, the among-groups design illustrated in Figure 11 was selected.

Consistent with recommendations by Schwab (1987) for extended training, this design devoted one day to SIMNET-D/POSNAV familiarization training. One day each was also included for crew testing and platoon testing. An outline of the training and testing procedures used in the current research is contained in a later section (pp. 43 - 47).

Research Participants

One-hundred and eighty M1 and M60 soldiers from Fort Knox, Kentucky, served as tank crew members for this study. The soldiers were assigned in groups of twelve (one platoon leader, one platoon sergeant, two tank commanders, four drivers, and four gunners). These same soldiers were assigned to form four three-man tank crews and one 12-man platoon. Hence, a total of 15 tank platoons, 60 tank crews, participated in this research (i.e., n=15 for platoon evaluation and n=60 for crew evaluation). One tank platoon, four tank crews, was tested each week for 15 weeks beginning in March 1988 and ending in June 1988.

	DAY 1	DAY 2	DAY 3
POSNAV-G (5 platoons / or 20 crews)	Training	Tactical Road Marches (4)	Movement to Contact/ Hasty Attack (2)
POSNAV-T (5 platoons / or 20 crews)	Training	Tactical Road Marches (4)	Movement to Contact/ Hasty Attack (2)
POSNAV-C (5 platoons / or 20 crews)	Training	Tactical Road Marches (4)	Movement to Contact/ Hasty Attack (2)

Figure 11. Among-groups design used in the current experiment.

While Army unit commanders ultimately decided on the particular subjects who participated during each week of testing, subjects were required to be qualified in the tank position they served. Unit commanders were unaware of the experimental treatment scheduled for any particular testing week. Furthermore, each platoon was assigned to an experimental condition (POSNAV-G, -T, or -C) using a sampling without replacement randomization procedure (Keppel, 1982).

Tank crews were formed through a process of random assignment of the gunners and drivers to the platoon leader, platoon sergeant, or wingman tank. Tank crews and platoons participating in the current research were not intact, or formally established, Armor crews and platoons. They were collections of individual tank crew members assigned to form four crews or a platoon.

Confederate Loaders/Research Assistants

Four research assistants served as ammunition loaders for the tank crews evaluated in the current experiment. These research assistants were carefully trained as confederate loaders and data collectors. The primary reasons for using surrogate loaders were to (a) minimize the number of soldiers required for testing, (b) allow an on-tank observer to collect various behavioral and process measures, and (c) provide a training instructor for each crew. The loader position was especially suited for confederate occupancy because the loader has little influence over tank crew and platoon performance with regard to land navigation tasks.

To take full advantage of the standardization possible with SIMNET, loader behavior must be identical for all tank crews during the testing. To achieve this uniformity, the four loaders received extensive training on SIMNET. Each loader received more than 60 hours of SIMNET and behavioral observation training. This training included: (a) an overview of the M1 tank, including an extensive briefing on an actual M1A1 tank; (b) formal instruction on the navigational tasks and procedures currently used by soldiers; (c) time to practice, with SME guidance, the M1 tasks supported by SIMNET tank modules; (d) an overview of the POSNAV system; (e) time to practice using the POSNAV system; (f) a description of the crew and platoon training program and test exercises used in the current research; (g) time to pilot and revise training scripts; (h) instructions on collecting behavioral observation data; and, (i) time to pilot and revise data collection logs.

The loaders received an additional 50 hours of on-the-job training during the pilot stages of crew and platoon test exercise development. There were repeated opportunities during training for loaders to practice operating the SIMNET and POSNAV systems as well as use the training scripts and data collection logs.

The loaders were frequently evaluated by the research staff, each other, and the soldiers participating in the pilot research. Evaluations were focused on ensuring that behavior was identical among the four loaders.

Instruments

Several instruments were developed for use in the current experiment. These instruments include four crew tactical road marches, two platoon combat missions, and several paper-and-pencil tests. The development and objective of each of these instruments are described below and summarized in Table 1.

Crew Road March Development

The goal of the crew road march testing was to require tank crews to use POSNAV in a demanding navigational exercise. Road marches are navigational exercises requiring a tank crew to move from one location, the start point (SP), to a final location, the release point (RP), by following along a prescribed intermediate series of checkpoints (CPs). Road marches are a significant part

Table 1

Summary of Instruments Used in the Current Experiment

Instrument	Description	Objective
Crew Road Marches Alpha Bravo Charlie Delta	Navigational exercises requiring tank crews to move from a start point to a release point following a specific path of checkpoints.	Assess navigation performance differences among crews in control and POSNAV conditions.
Platoon Missions Alpha Bravo	Offensive Movement to Contact/Hasty Attack tactical missions, requiring tank platoons to operate in realistic, task-loaded combat environment.	Assess combat performance differences among crews in control and POSNAV conditions.
Biographical Questionnaire	Questionnaire completed by each test participant to gather background data, such as Armor experience and aptitude test scores.	Describe the sample and evaluate, post hoc, test group equivalence.
Land Navigation Skills Test	Paper-and-pencil map reading/land navigation test administered to each soldier.	Evaluate, post hoc, test group equivalence.
Task Difficulty Questionnaire	Questionnaire requiring tank crews to rate the difficulty of performing nine fundamental land navigation tasks. Crews rate difficulty of these tasks performed in their SIMNET test condition and in a real tank.	Assess task difficulty, workload, differences among crews in the control and POSNAV conditions.
POSNAV SMI Questionnaire	Questionnaire containing Likert rating items on the POSNAV interface and open-ended questions on POSNAV and SIMNET-D.	Evaluate soldier reactions to the POSNAV user interface.

of a tank crew's job. They are included in nearly every Armor mission. The process of developing these crew exercises involved four steps. The goal was to develop a psychometrically sound and tactically relevant set of exercises.

Step One. Land navigation and other tank crew tasks potentially affected by the introduction of the POSNAV system were identified from the task descriptions contained in several documents described earlier (e.g., ARTEP 71-2; FM 21-26; O'Brien & Drucker, 1981). The subtasks, conditions, and standards for each task were identified. This step was facilitated by a review of task analyses and road marches from earlier SIMNET studies (e.g., Gound & Schwab, 1988; Schwab, 1987).

Step Two. The SIMNET terrain base was examined to select and plot routes for each road march, as well as the tasks encompassing them. Routes were selected to represent the range of terrain features and conditions available in SIMNET. Map-based and vehicle-based reconnaissance of the SIMNET terrain as well as frequent exercise tryouts by the research staff resulted in numerous exercise revision cycles.

The basic goal which guided crew exercise development was to make the exercises sensitive to differences in crew navigational proficiency. To achieve this goal, the road marches were designed to stress navigational requirements.

First, the four initial road marches plotted were each about 40 kilometers long, with 7 segments each. Typical road marches are about five kilometers long with two checkpoints. Hence, what may be expected as a typical road march length is about the average length of one segment from the initial marches developed for this evaluation.

Second, Armor doctrine requires that route checkpoints be easily identifiable terrain features. Typically, checkpoints are major road junctions, bridge crossings, intersections, landmarks, or heavily populated areas. Checkpoints are normally selected to monitor movement progress by ensuring that units pass critical points within specified times. The road marches used in the current research, however, were specifically designed to demand navigational proficiency. Checkpoints were selected to require a high level of skill to effectively reach, not unlike the points selected for an infantry orienteering course.

Third, tank crews are trained to report checkpoints within 30 seconds from crossing the point. In the current marches, however, tank crews were required to stop at each checkpoint and report their own-tank location. This procedure ensured that each crew's accuracy in reaching each march checkpoint was precisely recorded.

Fourth, in many Armor road marches, tank crews must not only navigate, but also search for targets and other enemy activity.

The threat of enemy contact, however, was minimized in the current marches. The marches were designed to be primarily navigational exercises, with only a few isolated tactical events to trigger desired navigational responses. For example, isolated enemy artillery strikes, NBC areas, or river crossings were placed along road march paths to require tank crew to perform the navigational behaviors associated with reacting to enemy fire, bypassing obstacles, and fording rivers, respectively. Crews were expressly told to expect no target engagements and to focus entirely on navigation. In fact, the M1 simulators were initialized with no ammunition during these marches.

Finally, tactical movement is often road-bound. The current marches, however, were completely cross-country. Rather than having to make generally simple determinations of whether to turn right, left, or go straight at the next intersection or road junction, tank crews in the current evaluation had to navigate across rugged terrain, often marked by limited identifiable terrain features.

Step Three. Four draft road marches resulting from step two were pre-tested. This pre-testing occurred in two phases.

Initially, 16 soldiers at Fort Knox, Kentucky, completed and evaluated each march during December 1987. The soldiers were assembled to form four, four-man tank crews. The confederate loaders did not participate during this pre-testing phase. Each tank crew completed the four draft road marches twice during a three day period. One day was dedicated to familiarizing each crew with the current research effort and the SIMNET-D modules. The POSNAV system was still undergoing development. Hence, only the control condition could be evaluated.

During this initial pilot testing, alternative road march paths, checkpoint locations, and task sequences were evaluated. This stage of development was informal, and tank crew members were urged to give extensive feedback on the quality of the marches and to offer suggestions for improving them. While this stage of pilot testing produced some road march changes (e.g., route adjustments, task sequence changes), major march changes were avoided until more formal exercise evaluations could be completed with both control and POSNAV-G or POSNAV-T crews.

The greatest contribution of this evaluation was related to the operation of the SIMNET-D M1 simulators and other research tools, such as the Plan View Display and Semi-Automated Forces. Test controllers identified many logistical problems with the initial exercise administration and control procedures. For example, the occurrence of M1 simulator and other resource breakdowns indicated the need to develop procedures to account for equipment failures. In addition, the need for stricter administration procedures became apparent.

A more formal stage of road march pre-testing included an evaluation of the four road march exercises using two additional platoons. During this evaluation, the test controller followed the strict administration procedures designed for the actual testing, including a day of training and a day of platoon exercises, described later. One platoon was tested per week. One platoon, a control group, used current navigational procedures. The other platoon used the navigational tools available in the POSNAV-T or terrain map display condition.

This more formal pre-testing provided an opportunity to: (a) reevaluate the road march administration procedures; (b) ensure that the loaders/research assistants could collect behavioral measures in a standardized manner; (c) ensure that the desired data were being collected by SIMNET-D data collection capabilities; and (d) evaluate the psychometric characteristics of the crew performance measures of effectiveness.

Step Four. Feedback from both stages of the exercise pre-testing was examined to revise and finalize the road march exercises. Minor modifications were made to the testing and training administration procedures, the road march structures, and on-board research assistant and SIMNET-D data collection procedures. Three major changes included:

1. The road marches were determined to be too lengthy for most crews to complete in one day. Hence, they were shortened to 30 kilometers with five checkpoints. This reduction generally involved deleting the last two route segments from each march.

2. An additional task, report own location, was added to the road marches. This task involved periodically requesting crews to stop and report their current own-tank grid location. This task was randomly introduced four times during each march and provided additional indications of the crew's ability to maintain their orientation during the marches.

3. Procedures for restarting crews who became "hopelessly lost" were revised. Rather than letting "lost" crews continue until the road march time limit was reached, crews were told to report when they were lost. Thirty minutes after this report, the crews could receive their current grid location from the test controllers. Although this procedure was rarely necessary, it ensured that all critical data were collected for all crews (i.e., all road march tasks were completed).

One of the final crew road marches used in the current evaluation, Road March Charlie, is depicted in Figure 12. The remaining road marches used for this evaluation, Road Marches Alpha, Bravo, and Delta, are depicted in Appendix A.

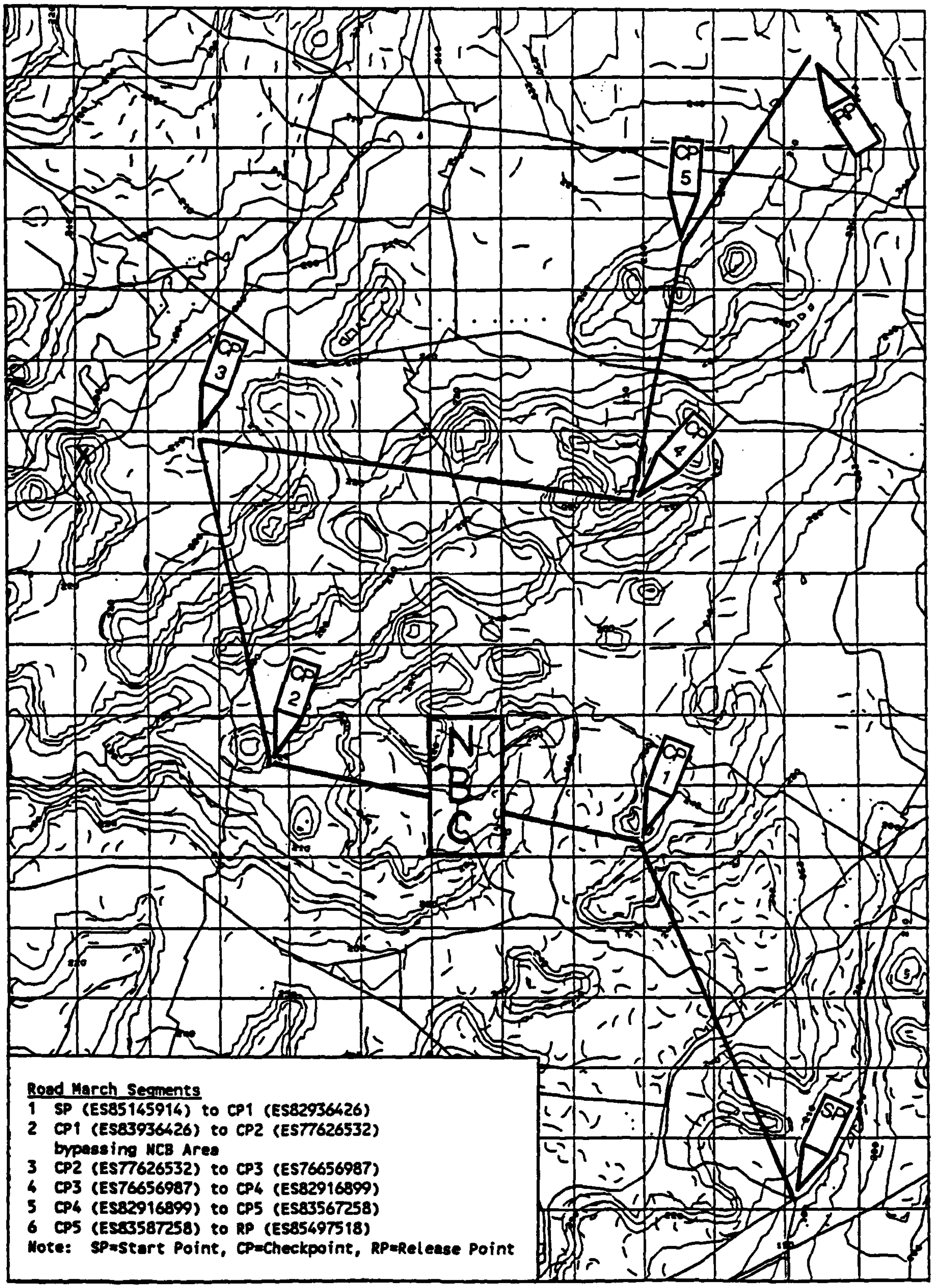

Figure 12. Map overlay for crew Road March Charlie.

Platoon Exercise Development

The crew road march exercises were designed to be essentially navigational exercises conducted in a limited tactical setting. The mission exercises, however, were specifically designed to require tank platoons to operate in a realistic, task-loaded combat environment. Experimental platoons were allowed use of the POSNAV display for tactical decision-making, maneuver, and gunnery in a coordinated response to a controlled OPFOR mission scenario. Baseline or control platoons used the navigational tools currently available for combat mission exercises, including a map, protractor, and mission OPORD with overlay. The mission exercises were constructed to consist of combat missions which involved a high degree of tactical movement in fluid situations and required frequent navigational adjustments, and effective command and control.

Platoon mission exercise development followed the five-step planning method outlined below and closely paralleled the mission training exercises found in FC 17-15-1. This five-step sequence was modeled after procedures used by other Army researchers in platoon scenario development. Exercise development was also coordinated with SMEs from the AEB and U.S. Army Command and Staff Department (C&S) to ensure that they were consistent with the latest changes in tactics, planning, and doctrine.

Step One. The prerequisite platoon tasks and drills, and any other tasks included in Armor missions were identified from the task descriptions and mission-task diagrams contained in several documents. These documents, described earlier, included ARTEP 71-2, FM 17-12-1, ARTEP 17-237-10-MTP, FM 71-1, FC 17-15, and O'Brien et al., 1981. The conditions, subtasks, and standards for each task were reviewed, along with platoon training exercise outlines. Emphasis was placed on identifying those missions and tasks which could potentially be affected by the POSNAV system. Previous platoon task analyses and mission exercises developed by the C&S and AEB (e.g., Gound & Schwab, 1988; Schwab, 1987) were models during the exercise development stage.

As a result of the current evaluation's emphasis on land navigation performance, the mission exercises were limited primarily to offensive missions. Platoons remain stationary for the bulk of most defensive missions. Missions which were included in the exercise domain included Movement to Contact, Hasty Defense, Hasty Attack, and resupply missions.

Step Two. The SIMNET terrain data base was examined by the research staff through both map-based and vehicle-based reconnaissance to select initial and final platoon positions for the mission exercises. Routes and fighting positions were selected between the initial and final positions to provide appropriate conditions for platoon task performance. Although selected task sequences were developed to fit the available terrain and to provide smooth transition from task to task, the general mission structures and graphics from two C&S mission exercises developed for SIMNET-T were used.

Step Three. The initial unit situation, mission orders, and external events required to trigger the performance of each task were developed as detailed as possible. Mission events were structured to initiate desired platoon responses. For example, the enemy vehicles (including size, location, and type) and artillery strikes were organized to require the platoon tanks to perform critical navigation, gunnery, and C^3 tasks in realistic, combat situations. Exercise tryouts by the researchers during this stage resulted in several revision cycles.

Step Four. An operations order (OPORD) and map overlay were prepared for each mission with routes and tactical graphic control measures indicated. Like the general mission structures, the mission operations orders and graphics were adapted from existing C&S materials. The orders and overlays portrayed the information and instructions that would be given by the company commander and platoon leader in an actual mission. Exercise outlines describing the sequence of mission tasks and drills included in each mission were also developed during this stage.

Step Five. The two combat mission exercises were pre-tested on SIMNET. The pre-testing occurred in two phases, paralleling the pre-testing of the crew road march exercises.

During the first stage, a platoon of soldiers--most of whom participated in the road march pre-testing--completed and evaluated the platoon mission exercises. This evaluation was informal and provided an opportunity to evaluate the general mission structures and administration procedures. The soldiers completed each of the two combat missions three times across three days. Each mission was completed once per day. The crew members within the platoon were told that the missions were in draft form and that their feedback and suggestions would be greatly appreciated.

Overall, the crew members offered many suggestions for mission improvement. These suggestions focused especially on improving the realism of exercise events, such as the response time for calls for fires, the placement of mission axes of advance, and enemy force capabilities. For example, the fire parameters for the OPFOR simulated by the SAF were set too high, resulting in situations where a single OPFOR vehicle could destroy the entire friendly tank platoon in seconds.

The test controllers also identified several problems with the mission administration procedures. For example, the need for procedures to account for the loss of friendly vehicles to enemy fire became clear. Furthermore, mission briefing procedures and scripts were found to be vague. The need to repeatedly stress important mission requirements, such as the requirement to transmit all spot and shell reports and report all graphic control measures, became readily apparent. SIMNET M1 simulator and other resource breakdowns also prompted the research staff to develop exercise procedures to account for test disruptions.

The second, more formal, stage of exercise pre-testing included an evaluation of the two combat mission exercises using the same two tank platoons who participated in the formal road march pilot. One platoon, a control group, completed the missions using current navigational tools and procedures, while the other platoon used the navigational tools available in the POSNAV-T display condition.

Like the formal road march pilot, this pre-testing effort provided an opportunity to: (a) reevaluate the mission administration procedures; (b) ensure that the confederate loaders could collect behavioral measures in a standardized manner; (c) ensure that the desired data were being collected by SIMNET-D data collection capabilities; and (d) evaluate the psychometric characteristics of the platoon performance measures of effectiveness.

<u>Step Six</u>. Feedback from both pilot stages of the exercise pre-testing was examined to revise and finalize the platoon mission exercises. Overall, the pilot results indicated that the loaders/research assistants could collect crew behavioral measures in a standardized manner. However, significant changes in the research assistant data collection logs suggested by the assistants were incorporated. The mission administration procedures also worked well and required only minor modifications. Three major mission changes, however, were made. These changes are described below:

1. Enemy vehicle and artillery strike locations along each mission route were refined. During the pilot runs, many platoons became lost early in the missions, resulting in a lack of data for many tasks contained in later mission stages. Hence, enemy vehicles and artillery strikes were placed outside the platoon's mission boundaries to (a) more realistically portray battlefield conditions possible in combat, and (b) allow the research staff to collect all critical platoon performance measures, even when the platoon deviated from the OPORD.

2. Like the road march exercises, the platoon mission exercises were revised to include an additional task, report own-tank location. This task was randomly initiated by the test controllers 10 times during each mission to provide an indication of the platoon's ability to maintain their orientation throughout the missions.

3. A twenty minute break was incorporated into each mission run. The missions, which initially ran about four hours (including OPORD and planning time), were reduced to three-and-a-half hours each. This break was set up to occur about two hours

into the exercise, the time most crews indicated that they would begin to feel "simulator sick," i.e., disorientated, uneasy, etc.

The two mission exercises used in the current research, Platoon Missions Alpha and Bravo, are depicted, with mission events described, in Figures 13 and 14, respectively.

Other Instruments

Although the four crew road march and two platoon mission exercises were the primary measurement instruments for determining the effect of alternative POSNAV displays on tank crew and platoon performance, respectively, other instruments were also developed. These other instruments included a biographical questionnaire, a map reading/land navigation skills paper-and-pencil test, a task difficulty questionnaire, and a POSNAV soldier-machine-interface (SMI) questionnaire. These instruments are contained in Appendix B. A description of each of these instruments follows.

First, a biographical questionnaire was developed to gather a variety of background data from each participant, including time in service, time in Armor, time at each tank crew position, experience on SIMNET, experience at NTC, and computer experience. Soldiers also signed a release permitting the research staff to obtain their Armed Services Vocational Aptitude Battery (ASVAB) scores. Existing biographical questionnaires used by ARI and acceptable to the Army were modified for the current research. The biographical questionnaire served not only to describe the sample, but also as a means to evaluate, post hoc, any systematic individual differences among groups not eliminated by treatment randomization.

To evaluate each tank crew member's map reading and navigation skills, a Land Navigation Skills Test (LNST) was developed. Similar tests used by the U.S. Army Armor School served as model exams during LNST development. The 18-item exam required tank crew members to demonstrate proficiency in reading a protractor, determining map distances, locating a grid coordinate on a map, performing resection, intersection, and polar plots, reading a tank odometer, and identifying critical terrain features. Throughout the test development, several SMEs, including four recent graduates of the Army Officer Advanced Course (AOAC) at Fort Knox, Kentucky and the soldiers who participated in the road march and mission pilot evaluations, completed and evaluated the test items. These SME reviews resulted in several test revisions. The soldiers indicated that the test was face valid. This test, like the biographical questionnaire, provided a means to evaluate, post hoc, treatment group equivalence.

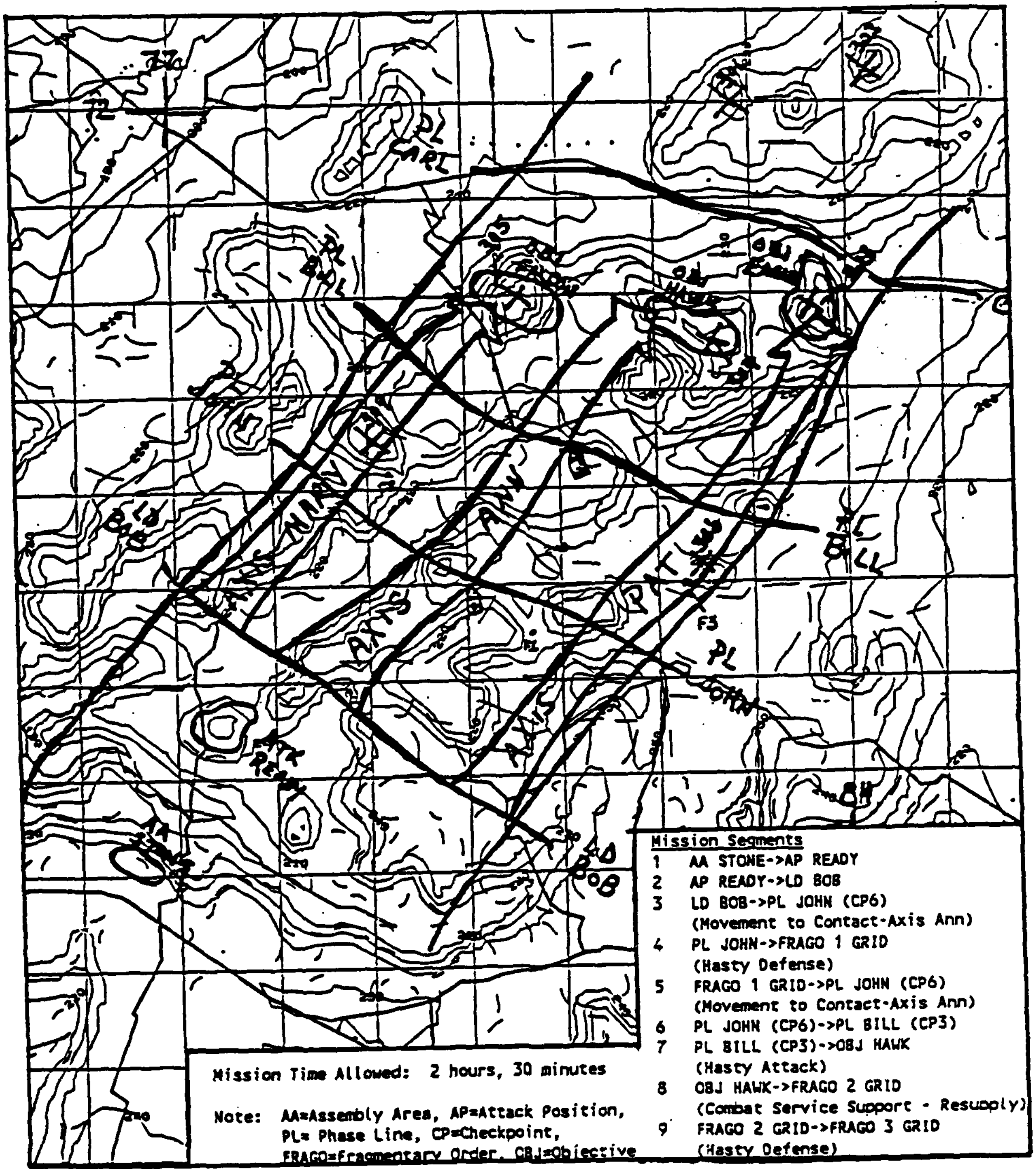

Figure 13. Operations Order (OPORD) map overlay for Platoon Mission Alpha: Movement to Contact/Hasty Attack (with change of mission).

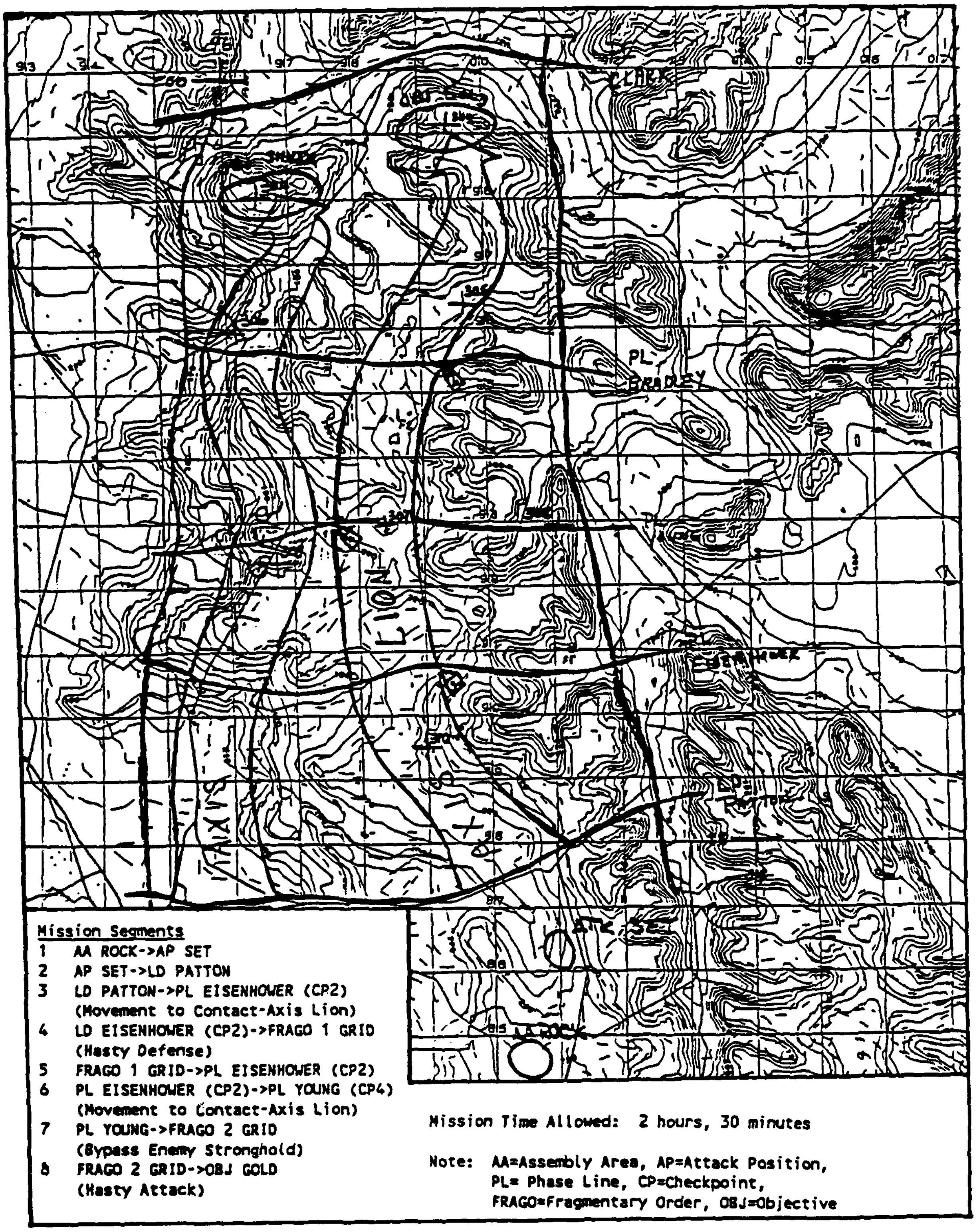

Figure 14. Operations Order (OPORD) map overlay for Platoon Mission Bravo: Movement to Contact/Hasty Attack (with change of mission).

A task difficulty questionnaire was also developed. This questionnaire required soldiers to assess the difficulty they experienced performing nine fundamental map reading and land navigation tasks in SIMNET (in their particular test condition) and the average difficulty of those same tasks in the real tank based on their field experiences. These tasks included determining one's own-tank grid location, determining one's own-tank reference heading, and maintaining platoon formations. This questionnaire was designed to indicate potential POSNAV training requirements and to evaluate the potential differences in task difficulty resulting from operating with POSNAV.

A POSNAV SMI questionnaire was also developed to evaluate soldier reactions to, or functional requirements of, the POSNAV user interface display and functions. This questionnaire contained 34 Likert items. Five open-ended questions were also included to evaluate soldier reactions to SIMNET-D and the familiarization training program, as well as suggestions for improving the POSNAV system. Interviews with pilot test subjects, reviews of similar SMI evaluation forms (e.g., Lickteig, 1986; Schwab, 1987), as well as SMI evaluation guidelines (e.g., Blackman, 1986; Cohill, Gilfoil, & Pilitsis, 1986; Dumas & Redish, 1986; del Galdo, Williges, Williges, & Wixon, 1986; Schell, 1986), guided the POSNAV SMI survey development.

Training and Testing Procedures

Using the among-groups design described earlier in Figure 11, the training and testing process required three days per tank platoon. Subjects in both the experimental and control groups received equal training time. Training addressed the navigational tools and procedures specific to their test condition. As only four M1 simulators were available, during each session one platoon (four tank crews) were trained and tested. These training and testing sessions are described below and outlined on an hour-by-hour basis in Table 2.

Day One: The Familiarization Training Program

The first day of each training/testing session was devoted entirely to training the four tank crews. The exact nature of this training--although generally similar with regard to training media and learning principles used--differed in content, depending on the experimental condition to which the platoon was assigned. In all conditions, training scripts and structured checklists were used by the instructors.

Regardless of experimental condition, the training occurred in four phases. During the first phase, the tank crews were given an overview of the SIMNET program and the research

Table 2

Training and Testing Procedures

Subjects	Support Personnel
1 Platoon Leader	4 Loaders/Research Assistants
1 Platoon Sergeant	2-3 Test Controllers
2 Tank Commanders	
4 Drivers	
4 Gunners	

DAY 1	0800-0945	SIMNET/Test Overview	SIMNET-D Classroom
	0945-1030	SIMNET Seat Specific Orientation	SIMNET-D M1s
	1030-1045	Break	SIMNET-D Break Area
	1045-1130	SIMNET/Land Navigation Condition-Specific Training Lecture	SIMNET-D Classroom
	1130-1230	Lunch Break	
	1230-1415	SIMNET/Land Navigation Condition-Specific Structured Practice	SIMNET-D M1s
	1415-1430	Break	SIMNET-D Break Area
	1430-1530	Individual Tank Road March Practice and Feedback	SIMNET-D M1s
	1530-1645	Platoon Tactical Mission Practice and Feedback	SIMNET-D M1s
	1645-1700	Group Discussion/Feedback	SIMNET-D Classroom
DAY 2		**** Crew Tactical Road March #1 ****	
	0800-0815	Brief Road March	SIMNET-D M1 Area
	0815-0950	Plan/Run Tactical Road March	SIMNET-D M1s
	0950-1010	Break	SIMNET-D Break Area
		**** Crew Tactical Road March #2 ****	
	1010-1025	Brief Road March	SIMNET-D M1 Area
	1025-1200	Plan/Run Tactical Road March	SIMNET-D M1s
	1200-1300	Lunch Break	
		**** Crew Tactical Road March #3 ****	
	1300-1315	Brief Road March	SIMNET-D M1 Area
	1315-1450	Plan/Run Tactical Road March	SIMNET-D M1s
	1450-1510	Break	SIMNET-D Break Area
		**** Crew Tactical Road March #4 ****	
	1510-1525	Brief Road March	SIMNET-D M1 Area
	1525-1700	Plan/Run Tactical Road March	SIMNET-D M1s
DAY 3		**** Platoon Tactical Mission Exercise Alpha ****	
	0800-0830	Issue Mission OPORD	SIMNET-D Classroom
	0830-0900	Mission Plan Time	SIMNET-D Classroom
	0900-1130	Mission Run Time	SIMNET-D M1s
	1130-1230	Lunch Break	
		**** Platoon Tactical Mission Exercise Bravo ****	
	1230-1300	Issue Mission OPORD	SIMNET-D Classroom
	1300-1330	Mission Plan Time	SIMNET-D Classroom
	1330-1600	Mission Run Time	SIMNET-D M1s
	1600-1700	Questionnaires and Debriefing	SIMNET-D Classroom

objectives. This overview included a description of the currentexperiment, the presentation of a SIMNET-D videotape, and a seat-specific orientation on the M1 simulator.

The seat-specific orientation session was conducted by the research assistants and designed to familiarize crew members with the differences in SIMNET crew positions and the actual M1 or M60A3 tank crew positions. Following this overview, the soldiers completed the biographical questionnaire and the LNST.

In the second phase of training, crews received classroom training. The crews in the control group received specific instructions on adapting to the navigational techniques and procedures unique to SIMNET (e.g., how to effectively use the SIMNET tank-based azimuth indicator). The crews in the two POSNAV conditions received classroom training on using the POSNAV system for land navigation purposes. This training, as suggested by the AEB and BBN (Huggins, 1986; Schwab, personal communication, 1987), emphasized when, how, and why the crews should use the POSNAV device.

In all test conditions, the classroom instruction was supported by numerous lecture aids, including hand out materials (e.g., SIMNET M1 operator manuals, SIMNET maps, and copies of the lecture outline), and overhead transparencies. The crew road march and platoon mission exercises, especially their administration procedures, were also described to each tank crew.

The third phase of the training provided each tank crew an opportunity to practice operating the SIMNET M1 tank and using the navigational resources available in their test condition. The research assistants conducted this training using structured training scripts which included a set of tasks for the crew members to practice. Assistants were trained to have each crew complete each task until they had repeatedly demonstrated proficiency.

Crews in the control condition were provided an opportunity to practice conventional navigation tasks such as using the grid azimuth indicator, turret reference system, and laser range finder, determining their own-tank location, and determining enemy vehicle locations. Crews in the POSNAV conditions practiced using the various functions available with POSNAV.

The final phase of the training provided each crew and platoon the opportunity to conduct a practice road march and practice mission exercise on SIMNET-D, respectively. These exercises were similar to those administered during the actual testing. During this phase, the research assistants and test controllers ensured that each crew used the navigational capabilities available to them.

The assistants and controllers also provided timely, specific, performance-based feedback to the crewmen to promote retention and transfer of the material taught during the earlier training phases. For example, checkpoint arrival, spot, shell, and own-location reports transmitted by each TC were promptly followed by the test controller telling the TC the actual grid location and how far off, in meters, their reported grid deviated from the actual grid.

Following the practice exercises, the crew members met for a group discussion/feedback session with the test controllers. This session focused on providing the crew members with feedback on their exercise performance and final instructions on actual testing requirements. Crew members were also urged to express their reactions to the training program.

Day Two: Crew Road March Testing

Actual testing began on the second day. This day was devoted to crew road march exercises. Four road march exercises were administered to each crew. A latin square administration design was used to allow each crew to complete different exercises at the same time. The four crews were randomly assigned to one of the four march administration orders shown in Table 3.

Table 3

Latin-Square Design for Crew Tactical Road March Administration

Road March Administration Order	Crew Tactical Road March			
	#1	#2	#3	#4
#1	Alpha	Bravo	Charlie	Delta
#2	Charlie	Alpha	Delta	Bravo
#3	Delta	Charlie	Bravo	Alpha
#4	Bravo	Delta	Alpha	Charlie

Before each road march began, each TC was given a road march order, SIMNET paper map with march overlay, protractor, and grease pencil. Crews were then allowed to begin their march planning. Before actually executing each march, however, crews were required to report that they had completed their planning and were ready to move out on the road march course. No time limit was placed on the road marches. All crews completed all four road marches in the one day provided.

Day Three: Platoon Mission Testing

The final day of testing was devoted to gathering platoon performance data. Each platoon conducted the two separate combat mission exercises depicted in Figures 13 and 14. As part of each mission, the platoons were given a 15-minute operations order briefing by the test controllers and 30 minutes to plan their mission. Each TC was also given a SIMNET paper map with march overlay, protractor, and grease pencil for use during each mission. Platoon leaders were also given copies of the mission OPORD and were urged to refer to it during the combat exercises when necessary.

Each platoon was allowed two hours and 30 minutes to complete each combat mission. Mission Alpha was administered first to all tank platoons, followed by Mission Bravo.

Following the testing, the crew members were debriefed on the objectives of the present experiment. During this debriefing, each crew, as a group, completed the task difficulty and POSNAV SMI questionnaires. Questions and comments by the crew members were addressed as completely as possible in a discussion session after the instruments were filled out. Crew members were also given instructions for obtaining a copy of the experiment's technical report upon completion of the evaluation, if they desired.

Criterion Measures

In developing crew and platoon measures of effectiveness (MOEs), ARTEP 71-2 and other sources for Armor task standards (e.g., Wheaton et al., 1980), as well as MOEs used by previous SIMNET researchers (e.g., Gound and Schwab, 1988; Schwab, 1987), were reviewed. The goal of this effort was to identify critical crew and platoon performance measures related to navigational proficiency and its effects on tactical operations.

A preliminary list of potential crew and platoon MOE constructs was then prepared and reviewed by Armor SMEs and researchers from the AEB, C&S, and ARI. The research staff also evaluated the capability to collect each measure using SIMNET-D resources. The results of the crew road march and platoon mission pre-testing also aided in selecting a final list of road march and mission exercise MOEs. The crew road march MOEs collected in the current research are described in Table 4. The platoon mission MOEs collected are detailed in Table 5.

Table 4

Crew Tactical Road March Measures of Effectiveness

Measure	Definition
RUNTIME	Mean time in minutes to execute each march, not including any planning time, averaged across all marches.
PLANTIME	Mean time in minutes to plan each march, averaged across all marches.
CPDEV	Mean deviation in meters between actual and reported checkpoint locations, averaged across all marches. Each march consists of five checkpoints and a release point.
LRDEV	Mean deviation in meters between actual and reported own-tank location, averaged across all marches. This measure was collected four times per march.
LRTIME	Mean time in seconds to report own-location, collected four times per march.
NBC	A dichotomous measure indicating crew success in bypassing a NBC area in road march Charlie (1 indicates successful bypass, 0 indicates unsuccessful bypass).
DISTANCE	Mean distance travelled in kilometers to execute each march, averaged across all marches.
FUEL	Mean fuel used in gallons to execute each march, averaged across all marches.
VEL	Mean tank velocity during each march, averaged across all marches.
MOVE	Mean tank velocity while moving during each march, averaged across all marches.
PCT0	Mean percent of time crew was at a halt during each march, averaged across all marches.
TCCOM	Mean number of TC to driver navigation-related communications during each march, averaged across all marches. This measure was collected by research assistants.
DVRCOM	Mean number of driver to TC navigation-related communication during each march, averaged across all marches. This measure was collected by research assistants.
PCTVBS	Mean percent of time the TC used the SIMNET-D M1's vision blocks during each march, averaged across all marches. This is a composite of the TC and research assistant ratings.
PCTMAP	Mean percent of time the TC used the SIMNET paper map during each march, averaged across all marches. This is a composite of the TC and research assistant ratings.
PCTPOS*	Mean percent of time the TCs used POSNAV during each march, averaged across all marches . This is a composite of TC and research assistant ratings.

* This rating is applicable only to the POSNAV-G and POSNAV-T test conditions.

Table 5

Platoon Combat Mission Measures of Effectiveness

Measure	Definition
MSNSDONE	Number of missions successfully executed, out of the two administered, within the two-and-a-half hours limit.
NODONE	Number of mission events successfully executed across all missions. The two missions contained 17 events.
MSNTIME	Mean time in minutes used per successfully executed event, averaged across all missions.
MSNFUEL	Mean fuel in gallons used per successfully executed event, averaged across all missions.
MSNDIST	Mean distance travelled in kilometers per successfully executed event, averaged across all missions.
MSNDISP	Mean number of seconds per successfully executed event at least one crew is dispersed from the platoon leader's tank by more than 1000 meters in mission Alpha or 600 meters in mission Beta. This measure is averaged across all missions.
MSNSRA	Mean deviation in meters between actual and reported own-tank locations, collected 10 times per mission. This measure is averaged across all missions.
MSNARTA	Mean deviation in meters between actual and reported artillery fire locations, collected 10 times per mission. This measure is averaged across all missions.
MSNARTT	Mean time in seconds to report the artillery fire locations, collected 10 times per mission. This measure is averaged across all missions.
MSNSTA	Mean deviation in meters between actual and reported enemy locations, collected 15 times per mission. This measure is averaged across all missions.
MSNSTT	Mean time in seconds to report the enemy locations, collected 15 times per mission. This measure is averaged across all missions.
FRAGDONE	Number of fragmentary orders (FRAGOs) successfully executed, averaged across all missions. The two missions contained a total of five FRAGOs.
FRAGTIME	Mean time to successfully execute the first mission FRAGO, averaged across all missions.
FRAGFUEL	Mean fuel used in executing the first mission FRAGO, averaged across all missions.
FRAGDIST	Mean distance travelled in kilometers by the platoon leader to execute the first mission FRAGO, averaged across all missions.
MSNPCT0	Mean percent of time each tank was at a halt, averaged across all missions.

Table 5 (continued)

Platoon Combat Mission Measures of Effectiveness

Measure	Definition
MSNTCCOM	Mean number of TC to driver navigation-related communications per successfully executed event, averaged across all missions.
MSNDVRCOM	Mean number of driver to TC navigation-related communications per successfully executed event, averaged across all missions.
MSNVBS	Mean percent of time the TCs used the SIMNET-D M1's vision blocks, averaged across all missions. This is a composite of TC and research assistant ratings.
MSNMAP	Mean percent of time the TCs used the SIMNET paper map, averaged across all missions. This is a composite of TC and research assistant ratings.
MSNPOS*	Mean percent of time the TCs used POSNAV, averaged across all missions. This is a composite of TC and research assistant ratings.

* This rating is applicable only to the POSNAV-G and POSNAV-T test conditions.

All criterion measures, with the exception of those otherwise indicated below, were automatically captured using Data Logger and DataProbe programs.

Five measures were collected by the research assistants and/or tank crew commanders for both the crew road march and platoon mission exercises. The research assistants noted the number of TC and driver navigation-related communications that occurred during each road march and mission exercise. Both research assistants and tank commanders also provided independent estimates of the percent of time the commander spent using the SIMNET paper map, looking out the tank's vision blocks and sights, and, if applicable, using the POSNAV display during each test exercise.

Although specific POSNAV interface effectiveness measures--such as the time TCs spent using various POSNAV functions or the number of TC POSNAV entry errors--were anticipated, the POSNAV system was, unfortunately, not instrumented to provide an audit trail capability to support these measures.

Other test instruments used in the current research provided measures for evaluating the POSNAV system. Individual and composite ratings of task difficulty for nine fundamental land navigation tasks were provided by all commanders. Participants rated (a) the difficulty of performing each task in SIMNET given the navigational procedures available in their condition, baseline or POSNAV aided, and (b) the difficulty of these same tasks in an actual M1 tank using conventional, nonautomated, navigational procedures. Difference score measures, examined for each task and overall, were computed to reflect the disparity in difficulty between the land navigation tasks performed in SIMNET and the real tank. The POSNAV SMI questionnaire also provided numerous measures for evaluating specific POSNAV system features.

Data Analyses

The data analyses were performed in four phases. First, analyses of the soldier data from the biographical questionnaire, LNST, and ASVAB were completed. These analyses were designed to evaluate, *post hoc*, the success of the treatment randomization procedure used in the current research. Multivariate analysis of variance (MANOVA), an extension of univariate analysis of variance (ANOVA) designed to simultaneously test differences among groups on multiple dependent measures, was used to analyze these data (Barker & Barker, 1984).

Second, the crew road march data were analyzed to evaluate the effects of POSNAV on crew performance. MANOVA was performed, with follow-up univariate ANOVAs, to analyze group differences on the crew road march MOEs. Two *a priori* ANOVA orthogonal comparisons were evaluated to test the difference between (a) the POSNAV-G and -T experimental groups, and (b) the control group and the two experimental (POSNAV) groups. *Post hoc* Tukey Honestly Significant Test (HST) comparison procedures were also used. Discriminant analysis also provided a means to evaluate the relative importance of the crew measures in distinguishing between the three test groups.

Third, the platoon mission data were analyzed. The limited platoon sample size and the number of platoon MOEs prohibited using MANOVA. Hence, univariate ANOVAs with the same two planned orthogonal comparisons used for road march analyses were performed. Tukey *post hoc* HST group comparison procedures were also used.

Finally, the task difficulty and POSNAV SMI questionnaire data were analyzed. Descriptive analyses and *t* tests were the primary means used for evaluating these data.

Privacy Procedures

Throughout the conduct of this research, including both the pilot and actual test administrations, the confidentiality of all subject responses was maintained. Whenever possible, subjects were identified by number. Subjects were assured of the confidentiality of their responses and performance prior to completing any questionnaires or tests or participating in SIMNET exercises.

Results

Group Equivalence Analyses

No significant differences between the three experimental conditions were detected on any of the eight soldier measures evaluated to assess group equivalence. Table 6 presents the overall mean and standard deviation for each of these soldier measures by tank position. These data were collected to evaluate, post hoc, treatment group equivalence and to assess the sample's representativeness. Soldier measures evaluated include Armor experience, test tank position experience, NTC experience, ASVAB Combat Orientation (CO) and General Technical (GT) scores, LNST score, SIMNET experience, and computer experience. The means and standard deviations for these measures by test group, POSNAV-G, -T, and -C, as well as all MANOVA analyses, are included in Appendix C. Data in Appendix C are also presented by tank position (i.e., platoon leader, platoon sergeant, tank commander, driver, and gunner). Platoon leaders do not complete the ASVAB. Hence, CO and GT scores are not indicated for this tank position.

Crew Road March Analyses

Table 7 presents the means and standard deviations by treatment group for the crew road march MOEs collected. Overall, crew performance was widely dispersed, particularly for crews in the control condition (POSNAV-C). Some measures, like checkpoint deviation (CPDEV) and own-location report deviation (LRDEV), have standard deviations 50 percent greater than the measure's mean value. The correlation matrix for the crew road march measures of effectiveness is included in Appendix D. The crew road march measures are highly intercorrelated, with only 21 of the 210 correlation coefficients not reaching significance.

The results of the omnibus MANOVA performed for the crew measures, shown in Table 8, indicated a significant test group main effect. Follow-up univariate planned comparisons, shown in Table 9, indicate that the POSNAV-A and -B groups performed significantly better on every road march criterion measure collected, with the highest t-value probability being .006.

No corrections were made for family-wise error because of the limited sample size and, hence, statistical power, of the crew evaluation. Even with a Bonferri t correction (for 30

Table 6

Means and Standard Deviations for Soldier Data: Overall and by Tank Position

Measure		Tank Position					
		Overall	Platoon Leader	Platoon Sergeant	TC	Driver	Gunner
TANKTIME	M	57.02	9.40	120.93	90.33	34.07	59.23
	SD	49.91	13.56	50.23	39.23	27.51	51.78
	N	180	15	15	30	60	60
JOB_EXP	M	21.67	2.47	44.60	43.97	8.80	22.45
	SD	27.60	4.44	28.20	33.95	15.99	25.41
	N	180	15	15	30	60	60
NTCCOUNT	M	.58	.07	.93	.67	.47	.69
	SD	.97	.26	1.39	.80	1.12	.82
	N	177	15	15	30	59	58
CO	M	109.57	*	115.31	107.90	110.59	108.07
	SD	12.83		14.34	11.06	13.70	12.24
	N	159		13	29	59	58
GT	M	107.70	*	111.40	106.21	108.32	106.88
	SD	12.07		13.80	10.79	13.09	11.19
	N	159		15	29	59	59
LNTSCORE	M	10.92	15.40	13.00	11.80	9.47	10.30
	SD	4.42	2.03	2.62	3.65	4.53	4.50
	N	180	15	15	30	60	60
SIM_EXP	M	8.99	11.47	9.67	8.10	10.32	7.12
	SD	18.05	25.63	16.96	19.02	18.91	14.88
	N	180	15	15	30	60	60
COMP_EXP	M	2.31	3.13	2.20	2.17	2.18	2.32
	SD	.97	.92	1.21	.99	.91	.89
	N	180	15	15	30	60	60

* Platoon Leaders are not required to complete the ASVAB.

Note: TANKTIME is number of months in Armor. JOB_EXP is number of months at test tank position. NTCCOUNT is number of times at Army National Training Center. CO is ASVAB Combat Orientation score. GT is ASVAB General Technical score. LNTSCORE is Land Navigation Skills Test score. SIM_EXP is number of hours previously spent on SIMNET. COMP_EXP is a self-reported rating of computer experience on a four-point scale (i.e. 1 = no experience, 2 = limited experience, 3 = some experience, 4 = considerable experience). M is the mean, SD is the standard deviation, and N is the number of valid observations.

Table 7

Means and Standard Deviations for Crew Road March Measures of Effectiveness

Measure		Overall (N=60)	POSNAV-G (N=20)	POSNAV-T (N=20)	POSNAV-C (N=20)
			Test Group		
RUNTIME	M	52.86	42.04	44.24	72.32
	SD	15.49	3.38	4.89	10.46
PLANTIME	M	8.33	6.35	5.37	13.28
	SD	5.85	3.18	4.07	6.35
CPDEV	M	232.94	25.51	19.43	653.90
	SD	273.67	20.00	20.89	473.13
LRDEV	M	354.87	3.96	4.36	1056.30
	SD	771.18	.53	1.56	1034.37
LRTIME	M	35.17	7.35	7.15	91.00
	SD	43.78	1.98	1.98	31.98
NBC	M	.80	.90	.90	.60
	SD.	.40	.31	.31	.50
DISTANCE	M	32.85	31.70	31.94	34.90
	SD	3.39	.86	1.45	5.62
FUEL	M	45.86	43.94	43.77	49.88
	SD	5.96	2.19	3.84	8.08
VEL	M	39.58	45.81	43.97	28.96
	SD	8.49	3.07	4.34	3.93
MOVE	M	52.62	55.04	52.72	50.11
	SD	4.47	2.93	3.18	5.52
PCT0	M	24.42	16.00	15.55	41.70
	SD	4.56	3.01	4.26	5.94
TCCOM	M	15.23	8.80	11.40	25.50
	SD	10.94	3.82	4.42	12.95
DVRCOM	M	3.20	1.75	2.65	5.20
	SD	4.08	2.31	2.28	5.86
PCTVBS	M	34.62	27.40	25.25	51.20
	SD	17.17	13.20	15.75	7.50
PCTMAP	M	31.47	27.90	17.70	48.80
	SD	17.05	11.07	13.97	7.50
PCTPOS	M	51.78	44.75	57.00	*
	SD	15.15	16.63	14.00	

* This measure is applicable only to the POSNAV-G and POSNAV-T test conditions (N=40).

Table 8

Omnibus MANOVA Tests for Crew Road March
Measures of Effectiveness

Main Effect: Test Group

Test	Value	Approx F	Hyp df	Err df	p
Pillais V	1.26482	5.04654	30	88.00	.000
Hotellings	22.08929	30.92500	30	84.00	.000
Wilk's lambda	.03052	13.54269	30	86.00	.000
Roys GCR	.95583				

Note: Test groups include POSNAV-G, POSNAV-T, and POSNAV-C.

planned comparisons, alpha=.0017), however, all but three measures--NBC (p=.006), DISTANCE (p=.002), and DVRCOM (p=.006)--would still show significant POSNAV versus no POSNAV differences.

Only one of the univariate planned comparisons for evaluating differences between the POSNAV-G and -T conditions was significant. As might be expected, crews in the POSNAV-G grid map display condition, without map terrain features, used the SIMNET paper map significantly more than the crews in the POSNAV-T terrain map display condition. This difference would persist with the Bonferri t correction. Tukey HST critical values for the crew march measures are presented in Appendix D.

The POSNAV system not only affected mean performance on each of the crew measures, but also affected the variance associated with most of the measures. The results of univariate tests for homogeneity of variance for crew measures, presented in Appendix D, indicates significant group differences in variance for 13 of the 15 measures. The performance of crews in the control group was significantly more variable than the performance of crews in the POSNAV-G or -T conditions on all but the mean tank velocity (VEL) and paper map usage (PCTMAP) measures. While both MANOVA and ANOVA procedures assume group variance homogeneity, their results are generally unaffected when this assumption is violated (Barker and Barker, 1984). As a precaution, however, the data were visually examined on scatter plots for potential outliers, but no outliers were found.

The discriminant analysis resulted in two canononical discriminant functions (see Appendix D). Only the first function reached statistical significance. The first of these two functions accounts for nearly 98 percent of the variance in the treatment group classification.

Table 9

Summary of Univariate ANOVA Test Group Main Effect for Crew Road March Measures of Effectiveness

Planned Comparison: POSNAV-G and POSNAV-T vs. POSNAV-C

Measure	Value	Std Error	T-Value	df	p
RUNTIME	-3501.84	228.25	-15.34	57	.000
PLANTIME	-890.95	155.35	-5.74	57	.000
CPDEV	-1262.87	149.90	-8.43	57	.000
LRDEV	-2104.28	327.10	-6.43	57	.000
LRTIME	-167.50	10.15	-16.50	57	.000
NBC	.60	.21	2.85	57	.006
DISTANCE	-6164.66	1855.24	-3.32	57	.002
FUEL	-12.06	2.91	-4.14	57	.000
VEL	31.86	2.09	15.23	57	.000
MOVE	7.54	2.22	3.40	57	.001
PCT0	-51.85	2.50	-20.74	57	.000
TCCOM	-30.80	4.49	-6.86	57	.000
DVRCOM	-6.00	2.12	-2.83	57	.006
PCTVBS	-52.75	6.45	-8.18	57	.000
PCTMAP	-51.98	5.64	-9.22	57	.000

Planned Comparison: POSNAV-G vs. POSNAV-T

Measure	Value	Std Error	T-Value	df	p
RUNTIME	-131.91	131.78	-1.00	57	.321
PLANTIME	58.75	89.69	.66	57	.515
CPDEV	6.08	86.54	.07	57	.944
LRDEV	-.40	188.85	-.00	57	.998
LRTIME	.20	5.86	.03	57	.973
NBC	.00	.12	.00	57	1.000
DISTANCE	-234.57	1071.12	-.22	57	.827
FUEL	.17	1.68	.10	57	.920
VEL	1.85	1.21	1.53	57	.132
MOVE	2.32	1.28	1.81	57	.076
PCT0	.45	1.44	.31	57	.756
TCCOM	-2.60	2.59	-1.00	57	.320
DVRCOM	-.90	1.22	-.74	57	.465
PCTVBS	.85	3.72	.23	57	.820
PCTMAP	11.83	3.25	3.63	57	.001

Examination of the standardized discriminant function coefficients and pooled-within-groups correlations (also included in Appendix D) as well as the group centroid plots shows that all but four of the road march measures are associated with the first function. These measures account primarily for the differences between the POSNAV (POSNAV-G and -T) and no POSNAV (POSNAV-C) conditions. Percent of time at a halt (PCT0), own-location report deviation (LRDEV), own-location report time (LRTIME), march run time (RUNTIME), and velocity (VEL) measures are principal components of function 1.

The four measures associated with function 2 account primarily for POSNAV-G and -T differences. Percent of time spent using the paper map (PCTMAP) is the principal component of the second, nonsignificant, function.

Table 10 shows the classification results for the two discriminant functions. Overall, the functions correctly classified 100 percent of the POSNAV-C crews but could only correctly classify 80 percent of the POSNAV-G and -T crews. These findings parallel the univariate ANOVA comparison findings described earlier.

Table 10

Classification Results from Discriminant Analysis for Crew Road March Measures of Effectivness

		Predicted Group Membership		
Test Group	N	POSNAV-G	POSNAV-T	POSNAV-C
POSNAV-G	20	16 80%	4 20%	0 0%
POSNAV-T	20	4 20%	16 80%	0 0%
POSNAV-C	20	0 0%	0 0%	20 100%

Percent of Cases Correctly Classified: 86.67%

Finally, for clarity the major findings are presented in Table 11 to reflect the percentage of improvement in the POSNAV groups' crew road march mean performance relative to the control groups' mean performance. Dependent measures are also described in operational terms rather than as acronyms.

Table 11

Summary of Crew Road March Findings for Primary Objective Measures of Effectiveness: Group Mean (M) and Percentage Improvement Relative to Control Group (%)

Measure	Control M	POSNAV-G M	POSNAV-G %	POSNAV-T M	POSNAV-T %
Error in reporting checkpoints in meters	654	26	96	19	97
Time to execute road march in minutes	72	42	42	44	39
Velocity during road march in kms/hr	29	46	159	44	152
Percent of time spent at a halt	42	16	62	16	62
Percent success in bypassing NBC area	60	90	150	50	150
Distance travelled during road march in kms	35	32	9	32	9
Fuel used during road march in gallons	50	44	12	44	12
Time to plan road march in minutes	13	6	54	5	62
Time to report own location in seconds	91	7	92	7	92
Error in reporting own location in meters	1056	4	99.6	4	99.6

Note: POSNAV-G is POSNAV with grid display format. POSNAV-T is POSNAV with terrain display format. All POSNAV-G and -T means are significantly different from the control (or no POSNAV) means ($p<.05$). No POSNAV-G and -T mean differences are significantly different ($p>.05$). % is percent of performance improvement of POSNAV mean (M) performance relative to control mean (M). For example, POSNAV-G crews reported checkpoints 96% more accurately than control crews.

Platoon Mission Analyses

Table 12 shows the means and standard deviations, by test condition and overall, for each of the 21 platoon performance measures collected. Like crew road march performance, platoon mission performance was highly variabile, particularly for the control condition (POSNAV-C). This variability is especially apparent with platoon vehicle dispersion (MSNDISP), own-location and artillery report accuracy (MSNSRA and MSNARTA), and fragmentary order distance travelled (FRAGDIST) measures.

Table 12

Means and Standard Deviations for Platoon Mission Measures of Effectiveness

Measure		Overall (N=15)	POSNAV-G (N=5)	Test Group POSNAV-T (N=5)	POSNAV-C (N=5)
MSNSDONE	M	1.27	1.80	1.80	.20
	SD	.88	.45	.45	.45
NODONE	M	15.33	16.60	16.80	12.60
	SD	2.35	.89	.45	2.07
MSNTIME	M	1095.47	913.16	923.12	1450.14
	SD	312.37	159.05	138.54	247.22
MSNFUEL	M	5.26	4.59	4.66	6.51
	SD	1.60	1.43	1.24	1.54
MSNDIST	M	1955.75	1839.36	1723.33	2304.56
	SD	454.02	342.95	183.15	577.74
MSNDISP	M	894.02	417.09	280.97	1984.00
	SD	1254.29	200.52	176.45	1787.69
MSNSRA	M	271.37	5.31	4.09	804.70
	SD	424.51	2.56	1.77	312.05
MSNSRT	M	25.51	17.74	11.88	46.92
	SD	21.94	9.29	9.25	25.14
MSNARTA	M	543.64	512.50	369.36	749.07
	SD	211.34	146.02	69.11	195.69
MSNARTT	M	44.33	37.48	38.31	57.21
	SD	17.87	15.55	13.71	19.42
MSNSTA	M	602.40	575.60	383.66	847.95
	SD	233.17	150.38	78.64	159.42

Table 12 (continued)

Means and Standard Deviations for Platoon Mission Measures of Effectiveness

Measure		Overall (N=15)	POSNAV-G (N=5)	Test Group POSNAV-T (N=5)	POSNAV-C (N=5)
MSNSTT	M	71.83	69.89	49.73	95.88
	SD	32.34	31.43	20.61	30.15
FRAGDONE	M	3.93	4.60	4.80	2.40
	SD	1.39	.89	.45	1.14
FRAGTIME	M	2481.80	1874.70	2191.50	3379.20
	SD	919.14	247.44	644.20	952.86
FRAGFUEL	M	10.76	6.86	10.53	14.89
	SD	5.25	1.90	3.65	6.25
FRAGDIST	M	8341.68	7073.78	7024.10	10927.16
	SD	3598.76	2109.80	2926.31	4447.34
MSNPCT0	M	22.53	20.45	17.50	29.65
	SD	8.37	5.33	8.19	7.01
MSNTCCOM	M	5.03	4.64	4.31	6.10
	SD	1.62	1.25	1.46	1.80
MSNDVRCOM	M	1.33	1.34	1.58	1.06
	SD	.56	.50	.67	.48
MSNVBS	M	56.42	50.44	51.46	67.35
	SD	10.68	5.37	8.68	8.40
MSNMAP	M	20.16	17.36	10.47	32.65
	SD	10.97	1.15	5.21	8.40
MSNPOS	M	35.14	32.20	38.07	*
	SD	6.65	5.54	6.87	

* This measure is only applicable to platoons in the POSNAV-G and POSNAV-T test conditions. Overall N = 10 for this measure.

Univariate ANOVA planned comparisons for each of the platoon performance measures were performed. Table 13 shows the results of these analyses. Tukey HST critical values for each of the platoon performance measures are included in Appendix E. For the planned comparison, all but four of the platoon measures show significant differences between the POSNAV conditions, POSNAV-G and -T, and the control condition (POSNAV-C). The four measures which did not show POSNAV versus no POSNAV differences were time to report artillery strikes (MSNARTT, p=.053), FRAGO distance travelled (FRAGDIST, p=.053), number of TC to driver communications (MSNTCCOM, p=.078), and number of driver to TC communications (MSNDVRCOM, p=.221).

As with the road march planned comparison analyses, no correction was performed to account for familywise error. With a Bonferri t correction (alpha=.0012), with 40 planned comparisons, only seven platoon measures would continue to show significant POSNAV versus no POSNAV group differences. Adjusted for Bonferri t, MSNFUEL (p=.031), MSNDIST (p=.035), MSNDISP (p=.017), MSNSRT (p=.004), MSNARTA (p=.002), MSNSTT (p=.036), FRAGTIME (p=.004), FRAGFUEL (p=.022), MSNPCTO (p=.016), and MSNVBS (p=.002) would no longer show significant group differences.

The primary reason for not correcting for familywise error is the statistical power the available crew and, especially, platoon sample sizes afforded for detecting differences. The researchers are concerned with the trade-offs between Type I and II errors and statistical power. With a familywise error correction, the probability of committing a Type II error, i.e., finding no differences when group differences actually exist, is higher. Without a familywise error correction, the probability of committing a Type I error, i.e., finding a group difference when no difference actually exists, is higher. Hence, the relative costs and benefits of committing Type I and II errors ultimately determine a researcher's analysis strategy.

In the current evaluation, Type II errors are considered more costly than Type I errors, particularly given the available sample size and relatively low probability levels attained. Future POSNAV developmental efforts may depend on the findings of this experiment. The researchers, knowing that future efforts will further define the effects of POSNAV on crew and platoon effectiveness, would rather risk committing Type I errors than underestimate potential POSNAV contributions.

Only one measure showed a significant difference between the POSNAV groups. Platoons with the POSNAV terrain map display (POSNAV-T) reported enemy locations more accurately than platoons with the POSNAV grid map display (POSNAV-G) (p=.043). This difference would not hold up to a Bonferri t correction.

Four of the platoon measures also showed significant group variance differences. Univariate tests of homogeneity of variance, included in Appendix E, indicate significant group variance differences in the number of mission events completed (NODONE), platoon vehicle dispersion (MSNDISP), own-location report accuracy (MSNSRA), and own-location report time (MSNSRT). The data were visually examined on scatter plots for potential outlier points that could account for these variance differences, but no outliers were found. In all four cases, the performance of control group platoons was significantly more variable than the performance of POSNAV-equipped platoons.

Table 13

Summary of Univariate ANOVAs for Platoon Mission Measures of Effectiveness

Planned Comparison: POSNAV-G and POSNAV-T vs. POSNAV-C

Measure	Value	Std Error	T-Value	df	p
MSNSDONE	-3.200	.490	-6.532	12	.000
NODONE	-8.200	1.456	-5.632	12	.000
MSNTIME	1063.990	205.530	5.177	12	.000
MSNFUEL	3.774	1.542	2.448	12	.031
MSNDIST	1046.430	440.426	2.376	12	.035
MSNDISP	3269.942	1143.186	2.860	12	.014
MSNSRA	1600.006	197.367	8.107	12	.000
MSNSRT	64.220	17.935	3.581	12	.004
MSNARTA	616.286	160.490	3.840	12	.002
MSNARTT	38.630	17.964	2.150	12	.053
MSNSTA	736.636	147.261	5.002	12	.000
MSNSTT	55.380	18.749	2.954	12	.036
FRAGDONE	-4.600	.959	-4.796	12	.000
FRAGTIME	2692.200	744.084	3.618	12	.004
FRAGFUEL	12.400	4.732	2.621	12	.022
FRAGDIST	7756.454	3621.786	2.142	12	.053
MSNPCT0	21.352	7.606	2.807	12	.016
MSNTCCOM	3.21	1.665	1.927	12	.078
MSNDVRCOM	-.790	.612	-1.291	12	.221
MSNVBS	32.800	8.360	3.923	12	.002
MSNMAP	37.472	6.296	5.952	12	.000

Planned Comparison: POSNAV-G vs. POSNAV-T

Measure	Value	Std Error	T-Value	df	p
MSNSDONE	.000	.283	.000	12	1.000
NODONE	-.200	.841	-.238	12	.816
MSNTIME	9.958	118.663	.084	12	.935
MSNFUEL	.074	.890	.083	12	.935
MSNDIST	-116.026	254.280	-.456	12	.656
MSNDISP	-.150	.369	-.406	12	.692
MSNSRA	-1.226	113.950	-.011	12	.992
MSNSRT	-5.860	10.355	-.566	12	.582
MSNARTA	-143.138	10.824	-.893	12	.390
MSNARTT	.830	10.372	.080	12	.938
MSNSTA	-191.640	85.021	-2.258	12	.043
MSNSTT	-20.158	17.595	-1.146	12	.274
FRAGDONE	.400	.712	.562	12	.584
FRAGTIME	316.800	429.573	.737	12	.475
FRAGFUEL	3.668	2.732	1.343	12	.204
FRAGDIST	-49.678	2091.039	-.024	12	.981
MSNPCT0	-2.956	4.391	-.673	12	.514
MSNTCCOM	-.364	.860	-.423	12	.712
MSNDVRCOM	.246	.353	.696	12	.500
MSNVBS	1.024	4.827	.212	12	.836
MSNMAP	-6.896	3.635	-1.897	12	.082

Finally, the major findings are presented in Table 14 to clearly reflect the percentage of performance improvement in the POSNAV groups' platoon mission mean performance relative to the control groups' mean performance.

Survey Analyses

Task Difficulty Questionnaire

Thirty measures were evaluated from the task difficulty questionnaire. Table 15 presents the definitions for each of these measures. Table 16 shows the mean and standard deviation, by test condition and overall, for each of the difficulty measures. In general, crews rated few of the tasks as "quite difficult" or "extremely difficult." Nevertheless, individual ratings were quite variable.

Univariate ANOVA planned comparison findings for each task difficulty measure are included in Appendix F. These data parallel the road march and platoon findings. All but four of the 30 measures show significant differences between the POSNAV (POSNAV-G and -T) and no POSNAV (POSNAV-C) treatments, while only two measures show significant POSNAV-G and -T group differences.

The POSNAV crews (POSNAV-G and -T) indicated that they experienced less difficulty than the control condition crews in determining their own-tank location, determining their own-tank orientation, maintaining their own-tank orientation, determining the grid location of other objects, performing map-terrain association, navigating from one point to another, bypassing obstacles, and reacting to enemy fire. There was no difference between groups in task difficulty ratings for maintaining platoon formation. While both the POSNAV-G and POSNAV-G groups had immediate access to their current eight-digit UTM grid location, the POSNAV-T crews, with the terrain map, indicated that determining their own-tank location was significantly easier in their test condition.

An interesting finding is that the tank crews in the POSNAV-G and -T groups rate seven of the nine land navigation tasks as being significantly more difficult on the actual M1 tank in the field than the crews in the control condition. The crews in the POSNAV (POSNAV-G and -T) and no POSNAV (control) crews rated as equally difficult performing map-terrain association and maintaining platoon formations in the M1 tank in the field. There were no differences between the POSNAV-G and -T crew ratings of the difficulty of these nine tasks when performed in the M1 tank in the field.

Table 14

Summary of Platoon Tactical Mission Findings for Primary Objective Measures of Effectiveness: Group Mean (M) and Percentage Improvement Relative to Control Group (%)

Measure	Control	POSNAV-G		POSNAV-T	
	M	M	%	M	%
Missions successfully executed out of 2	.2	1.8	900	1.8	900
Mission events successfully executed out of 17	12.6	16.6	132	16.8	133
Time spent per mission event executed in minutes	24	15	37	15	37
Fuel used per mission event executed in gallons	7	5	29	5	29
Time per mission event executed with crew lost in minutes	33	7	79	5	85
Number of FRAGOs successfully executed out of 5	2.4	4.6	192	4.8	200
Time to execute FRAGO in minutes	56	31	45	37	34
Fuel used to execute FRAGO in gallons	15	7	53	11	27
Error in reporting enemy locations in meters	848	576	32	384	55
Time to report enemy locations in seconds	96	70	27	50	48
Error in reporting shell impacts in meters	749	512	32	369	51
Error in reporting own location in meters	805	5	99.4	4	99.5
Time to report own location in seconds	47	18	62	11	77

Note: POSNAV-G is POSNAV with grid display format. POSNAV-T is POSNAV with terrain display format. All POSNAV-G and -T means are significantly different from the control (or no POSNAV) means ($p<.05$). Only enemy location reporting error is significantly different between the POSNAV-G and -T groups ($p=.043$). % is percent of performance improvement of POSNAV mean (M) performance relative to control mean (M).

Table 15

Task Difficulty Questionnaire Measures

Task	Definition
SIM1	Tank crew's rating of the difficulty they experienced determining their own-tank location in SIMNET in their test condition.
SIM2	Tank crew's rating of the difficulty they experienced determining their own-tank orientation in SIMNET in their test condition.
SIM3	Tank crew's rating of the difficulty they experienced maintaining their own-tank orientation in SIMNET in their test condition.
SIM4	Tank crew's rating of the difficulty they experienced determining the grid location of other objects (e.g., spot reports) in SIMNET in their test condition.
SIM5	Tank crew's rating of the difficulty they experienced performing map-terrain association in SIMNET in their test condition.
SIM6	Tank crew's rating of the difficulty they experienced navigating from one point to another in SIMNET in their test condition.
SIM7	Tank crew's rating of the difficulty they experienced maintaining platoon formation in SIMNET in their test condition.
SIM8	Tank crew's rating of the difficulty they experienced bypassing obstacles (e.g., NBC areas) in SIMNET in their test condition.
SIM9	Tank crew's rating of the difficulty they experienced reorienting after reacting to enemy fire (e.g., air or artillery strikes) in SIMNET in their test condition.
SIM	The average of SIM1 thru SIM9.
TANK1	Tank crew's rating of the difficulty they experienced determining their own-tank location in an actual tank in their test condition.
TANK2	Tank crew's rating of the difficulty they experienced determining their own-tank orientation in an actual tank in their test condition.
TANK3	Tank crew's rating of the difficulty they experienced maintaining their own-tank orientation in an actual tank in their test condition.

Note: Task difficulty is rated on a seven-point scale (1 = extremely easy, 2 = quite easy, 3 = slightly easy, 4 = neither easy nor difficult, 5 = slightly difficult, 6 = quite difficult, 7 = extremely difficult).

Table 15 (continued)

Task Difficulty Questionnaire Measures

Task	Definition
TANK4	Tank crew's rating of the difficulty they experienced determining the grid location of other objects (e.g., spot reports) in an actual tank in their test condition.
TANK5	Tank crew's rating of the difficulty they experienced performing map-terrain association in an actual tank in their test condition.
TANK6	Tank crew's rating of the difficulty they experienced navigating from one point to another in an actual tank in their test condition.
TANK7	Tank crew's rating of the tank crew's rating of the difficulty they experienced they experienced maintaining platoon formation in an actual Tank in their test condition.
TANK8	Tank crew's rating of the difficulty they experienced bypassing obstacles (e.g., NBC areas) in an actual tank in their test condition.
TANK9	Tank crew's rating of the difficulty they experienced reorienting after reacting to enemy fire (e.g., air or artillery strikes) in an actual tank in their test condition.
TANK	The average of TANK1 thru TANK9.
SIMTANK1	Difference between the tank crew's rating of the difficulty they experienced determining their own-tank location in SIMNET and in an actual tank in their test condition.
SIMTANK2	Difference between the tank crew's rating of the difficulty they experienced determining their own-tank orientation in SIMNET and in an actual tank in their test condition.
SIMTANK3	Difference between the tank crew's rating of the difficulty they experienced maintaining their own-tank orientation in SIMNET and in an actual tank in their test condition.
SIMTANK4	Difference between the tank crew's rating of the difficulty they experienced determining the grid location of other objects (e.g., spot reports) in SIMNET and in an actual tank in their test condition.
SIMTANK5	Difference between the tank crew's rating of the difficulty they experienced performing map-terrain association in SIMNET and in an actual tank in their test condition.
SIMTANK6	Difference between the tank crew's rating of the difficulty they experienced navigating from one point to another in SIMNET and in an actual tank in their test condition.
SIMTANK7	Difference between the tank crew's rating of the difficulty they experienced maintaining platoon formation in SIMNET and in an actual tank in their test condition.
SIMTANK8	Difference between the tank crew's rating of the difficulty they experienced bypassing obstacles (e.g., NBC areas) in SIMNET and in an actual tank in their test condition.
SIMTANK9	Difference between the tank crew's rating of the difficulty they experienced reorienting after reacting to enemy fire (e.g., air or artillery strikes) in SIMNET and in an actual tank in their test condition.
SIMTANK	The average of SIMTANK1 thru SIMTANK9.

Note: Task difficulty is rated on a seven-point scale (1 = extremely easy, 2 = quite easy, 3 = slightly easy, 4 = neither easy nor difficult, 5 = slightly difficult, 6 = quite difficult, 7 = extremely difficult).

Table 16

Means and Standard Deviations for the Task Difficulty Questionnaire Measures

Land Navigation Task		Test Group			
		Overall (N=60)	POSNAV-G (N=20)	POSNAV-T (N=20)	POSNAV-C (N=20)
SIM1	M	2.55	1.70	1.10	4.85
	SD	2.10	1.63	.31	1.57
SIM2	M	2.28	1.75	1.45	3.65
	SD	1.86	1.59	1.10	2.01
SIM3	M	2.5	2.10	1.55	3.85
	SD	1.97	1.86	1.28	1.98
SIM4	M	3.35	2.90	2.40	4.75
	SD	1.78	1.65	1.05	1.68
SIM5	M	3.35	3.35	2.15	4.55
	SD	2.13	2.39	1.46	1.79
SIM6	M	2.27	1.90	1.10	3.80
	SD	1.73	1.65	.45	1.51
SIM7	M	4.25	4.30	4.00	4.45
	SD	1.77	1.92	1.45	1.96
SIM8	M	2.08	1.95	1.25	3.05
	SD	1.44	1.54	.44	1.47
SIM9	M	3.23	2.95	2.05	4.70
	SD	2.13	2.26	1.40	1.81
SIM	M	2.87	2.55	1.90	4.18
	SD	1.45	1.48	.43	1.09
TANK1	M	3.50	3.80	4.05	2.65
	SD	1.40	1.06	1.54	1.18
TANK2	M	3.00	3.30	3.45	2.25
	SD	1.51	1.34	1.73	1.16
TANK3	M	3.10	3.40	3.50	2.40
	SD	1.47	1.50	1.64	.99
TANK4	M	3.92	4.40	4.10	3.25
	SD	1.56	1.50	1.65	1.33
TANK5	M	2.95	2.85	3.30	2.70
	SD	1.42	1.27	1.63	1.34
TANK6	M	3.33	3.75	3.90	2.35
	SD	1.63	1.77	1.52	1.14

Table 16 (continued)

Means and Standard Deviations for the Task Difficulty Questionnaire Measures

Land Navigation Task			Test Group		
		Overall (N=60)	POSNAV-G (N=20)	POSNAV-T (N=20)	POSNAV-C (N=20)
TANK7	M	2.30	2.65	2.10	2.15
	SD	1.58	1.76	1.59	1.42
TANK8	M	3.33	3.95	3.50	2.55
	SD	1.58	1.70	1.54	1.19
TANK9	M	3.45	4.05	3.65	2.65
	SD	1.73	1.64	2.13	.99
TANK	M	3.21	3.57	3.51	2.55
	SD	1.06	.90	1.22	.71
SIMTANK1	M	-.95	-2.10	-2.95	2.20
	SD	2.94	2.22	1.70	1.71
SIMTANK2	M	-.72	-1.55	-2.00	1.40
	SD	2.78	2.40	2.25	2.44
SIMTANK3	M	-.60	-1.30	-1.95	1.45
	SD	2.87	2.74	2.35	2.37
SIMTANK4	M	-.57	-1.50	-1.70	1.50
	SD	2.40	2.19	1.69	1.85
SIMTANK5	M	.40	.50	-1.15	1.85
	SD	2.66	2.84	2.41	1.84
SIMTANK6	M	-1.07	-1.85	-2.80	1.45
	SD	2.73	2.56	1.71	1.79
SIMTANK7	M	1.95	1.65	1.90	2.30
	SD	2.35	2.44	2.34	2.34
SIMTANK8	M	-1.25	-2.00	-2.25	.50
	SD	2.18	2.13	1.65	1.61
SIMTANK9	M	-.22	-1.10	-1.60	2.05
	SD	2.81	2.49	2.62	1.79
SIMTANK	M	-.34	-1.03	-1.61	1.63
	SD	2.01	1.74	1.38	1.165

The task difficulty difference measures also indicate that the crews in the control condition (POSNAV-C) rated all but two of the tasks as being easier in the actual M1 tank in the field than in their SIMNET test condition. The POSNAV experimental groups, however, indicate the opposite. The POSNAV-G and -T crews rated the nine land navigation tasks as significantly easier in their SIMNET test condition than in the actual M1 tank in the field. As might be expected, the crews using POSNAV with the grid map (POSNAV-G) indicated that performing map-terrain association in SIMNET was significantly more difficult than the POSNAV-T crews, who used POSNAV with the terrain map. For a more complete discussion of these differences in task difficulty data, see Lickteig and Du Bois (1988).

Twenty-six of the 60 tank crews who participated in this research included comments with their task difficulty questionnaire ratings. The soldiers in the POSNAV-G and POSNAV-T conditions generally indicated praise for the POSNAV system. Comments from the crews in the control condition (POSNAV-C) were more varied. Some crews indicated problems with the SIMNET system, such as the lack of tank bumper number plates, the lack of realistic graphics, and the lack of appropriate padding on the radio headsets. Other crews, however, indicated that SIMNET provided a realistic environment for mounted land navigation.

POSNAV Soldier-Machine-Interface (SMI) Questionnaire

The mean, standard deviation, and frequency distribution for each of the 34 items on the POSNAV SMI evaluation questionnaire across both the POSNAV-G and -T groups are presented in Appendix G. Only one item showed a significant difference between the POSNAV-G and -T groups. As expected, crews with the terrain display (POSNAV-T), in comparison to crews with the grid display (POSNAV-G), reported that their POSNAV display was more helpful for navigating than the conventional paper map. *T* test findings are included in Appendix G.

Overall, while the frequency distributions show the wide dispersion of the crew ratings, the crews who used the POSNAV system generally indicated positive reactions to the POSNAV SMI. For example, the crews indicated that they thought the location of the commander's POSNAV display in the tank to the right of the GPSE (see Figure 10) was acceptable, that the POSNAV control and display functions were easy to use and easy to read, and that the POSNAV display allowed them more time to acquire targets. The crews indicated that drivers served a more important role in tank land navigation with the POSNAV system.

In addition to the 34 items on the POSNAV SMI questionnaire, the tank crews completed five open-ended survey items. These items, shown in Appendix B, asked the soldiers to offer suggestions for improving the POSNAV system, indicate what features of POSNAV were most helpful for navigation, offer suggestions for improving future POSNAV training programs, and indicate whether SIMNET provided an adequate environment for evaluating POSNAV. Participant responses to these open-ended items are summarized in the discussion section.

Discussion

Performance Effects of POSNAV

Overall, the POSNAV test results strongly support the utility of including a POSNAV display in the upgraded Block II M1A1 tank. Tank crews and platoons who used POSNAV performed significantly better than baseline crews and platoons who used conventional navigational tools, including a paper map, compass, and protractor.

These findings are especially compelling given (a) the limited number of crews and platoons who participated in this experiment, and (b) the post hoc group equivalence analyses, which demonstrated no significant group differences, overall or by test position, on eight important Armor personnel measures. These measures included Armor and job experience, NTC experience, SIMNET experience, computer experience, land navigation and map reading skills, and ASVAB CO and GT scores.

All of the 15 crew performance measures and all but four of the 21 platoon performance measures supported statistically significant differences between the crews and platoons who used the POSNAV display (POSNAV-G and -T crews and platoons) and the crews and platoons who did not use the POSNAV display (POSNAV-C crews and platoons).

Crews with POSNAV completed the road march exercises quicker, used less fuel, travelled less distance, moved at faster velocities, spent less time at a halt, reported checkpoint arrivals more accurately, reported their own-tank location quicker and more accurately, and required fewer TC to driver and driver to TC navigation-related communications than crews without POSNAV.

Platoons with POSNAV, compared to platoons without POSNAV, successfully completed the combat missions more frequently, completed more mission segments or events, successfully executed more fragmentary orders, used less fuel, travelled less distance, spent less time at a halt, maintained appropriate platoon vehicle dispersion more consistently, reported their own-tank locations faster and more accurately, reported target and shell locations more accurately, and reported target locations faster.

These crew and platoon differences appear quite meaningful from an operational perspective. The mean performance of the control condition (POSNAV-C) crews and platoons was often more than two and three standard deviations worse than the performance of the crews and platoons with POSNAV. The potential impact of POSNAV on close combat heavy operations is underscored by the evaluation's use of ARTEP small unit mission exercises. The Movement to Contact and Hasty Attack missions are regarded as, perhaps, the most frequent, demanding, and critical missions of the Maneuver Force. Both the Hasty Attack and the change of mission, FRAGO, are central to the doctrinal assumptions of the AirLand Battle--speed, agility, penetration, and synchronization.

In addition, crew and platoon performance was more consistent with POSNAV. For example, standard deviations for the performance of POSNAV-G and -T crews were frequently more than two and three times smaller than the standard deviations associated with the performance of POSNAV-C crews. This consistent pattern of performance for POSNAV-aided commanders is of particular importance in the conduct of multi-echelon military operations in which each individual unit's mission is integral to overall force effectiveness.

Reduced Commander's Workload

The results also indicate that POSNAV may significantly reduce the tank commander's workload. Currently, tank commanders must continuously perform map terrain association to determine their current location and maneuver route with respect to mission requirements. Commanders must then continuously monitor and guide drivers through navigation of the designated route. In fact, navigational information in the form of map data and mission route is typically unavailable to the driver. The POSNAV system not only provides continuous navigational updates to the commander, but the driver's display also provides continuous navigational data which is, in fact, more complete than that available to the tank commander and includes: digital readouts of the exact distance and direction to the next waypoint, and a steer-to indicator.

Both the mission and crew march data on tank commander to driver communications (MSNTCCOM and TCCOM) show substantial reductions in the number of navigational communications that commanders needed to guide their driver's execution of the crew and mission routes. Even with this reduction in navigational instructions, crews and platoons equipped with POSNAV more successfully executed these exercises and missions with respect to nearly every dependent measure collected.

This inference of reduced commander workload is also supported by the task difficulty data. POSNAV-equipped tank commanders rated seven of nine navigational tasks as significantly less difficult compared to control condition commanders. Tank commanders also stated on the POSNAV SMI Survey (questions 16-18) that with POSNAV they gave drivers more navigational responsibility and provided fewer navigational directions.

Similarly, there were fewer driver to tank commander navigational communications (MSNDVRCOM and DVRCOM) for POSNAV-equipped crews. These findings suggest that POSNAV allowed drivers to function more autonomously than they would have without POSNAV and are confirmed by soldier responses on the POSNAV SMI survey.

Grid Versus Terrain Display

There were few significant performance differences detected between the POSNAV-G and -T crews and platoons, particularly with the objective data. This lack of significant findings was not unexpected, given the limited statistical power the available sample size afforded for detecting differences.

Nevertheless, the lack of consistent support for a terrain requirement in the POSNAV display (i.e., POSNAV-G over POSNAV-T) is important. The results of this evaluation clearly indicate that even a grid map display will provide the Maneuver Force a significant edge in combat effectiveness.

The relative benefits of terrain maps awaits further investigation. The current terrain version of POSNAV, POSNAV-T, only marginally provided the enhanced terrain analysis capabilities anticipated for more advanced automated command and control systems (Blasche & Lickteig, 1984; Lickteig, 1986). More capable processing systems are expected to transform digitized terrain into much richer depictions of the battlefield, including slope and elevation shading, perspective views, and line-of-sight graphics. When coupled with rule-based protocols and artificial intelligence, digitized terrain may enable automated terrain analysis essential to effective military planning and operations.

POSNAV's Potential Payoff to the Army

The soldier performance data provide a substantial body of evidence which demonstrates the potential payoffs to the Army of implementing POSNAV. While the authors are reluctant to presume they can adequately interpret the overall tactical benefits that Armor commanders might experience from a POSNAV implementation, the following comments are provided to further military experts' consideration of POSNAV's potential contribution.

First, it should be emphasized again that the present evaluation assessed the effects of POSNAV information integrated with a spatial display. This spatial display provided commanders a pictorial representation of their vehicle's location and orientation on the actual battlefield. This "picture" minimized the difficulty associated with crew and platoon requirements to continuously perform complex map reading tasks, such as contour interpretation, own location determinations, and other location determinations including: enemy targets, artillery strikes, and friendly forces.

The importance of this pictorial format, in contrast to a digital-only readout of one's location and orientation, should not be underestimated--particularly with respect to potential POSNAV effects. The digital only format would still require commanders to continuously transform and extrapolate own and other position data to a paper map medium.

Cumulative Effects

The effectiveness of crew and platoon battlefield information reporting is a function of both report timeliness and accuracy. While the crew and platoon results demonstrate significant improvements in both the speed and accuracy of own and other location reports, the cumulative effect of these factors should be stressed. Armor commanders can better estimate the tactical advantages of receiving not only the correct information, but also receiving the information in sufficient time to react to it.

Undoubtedly, commanders can recall training and/or combat situations in which military operations were severely compromised because battlefield reports were too inaccurate, or received too late to bring about appropriate courses of action. Estimates of the cumulative effect of speed and accuracy are, of course, dependent upon a wide variety of tactical factors and the urgency of the current mission. Nevertheless, the time and accuracy data base generated from this evaluation--particularly for the Movement to Contact and Hasty Attack missions--provides commanders, combat developers, and combat modelers a basis for deriving estimates of POSNAV's potential effect across a wide range of small unit combat missions.

Mission Complexity

The potential combat performance effects of POSNAV are best demonstrated by examining the platoon mission and change of mission, or FRAGO, data. This evaluation included crew performance exercises to provide a more comprehensive assessment of POSNAV on small unit performance and to obtain more reliable measures of any effects over a larger sample size (n=20 per condition for the crew level data versus n=5 for the platoon level data). However, tank crews rarely operate individually. Therefore, the platoon mission is more generalizable to current military combat operations. A close inspection of the mean values presented in Tables 7 and 12, comparing crew and platoon data, suggests that POSNAV's contributions are even greater in the context of platoon combat operations.

As might be expected, the more complex, unpredictable, and demanding the military operation, the more an automated navigational system such as POSNAV contributes to the successful execution of the operation. For example, the fuel expended data indicate POSNAV provided a 12 percent savings over control on crew road marches, a 29 percent savings on Movement to Contact and Hasty Attack missions, and a 54 percent savings for the execution of impromptu fragmentary orders, FRAGOs.

Similarly, while control platoons completed the majority of mission segments, the cumulative effect of POSNAV is more evident in the finding that only 10 percent of the missions were successfully executed by the control platoons compared to the 90 percent successful mission execution rate by the POSNAV-equipped platoons. Furthermore, the POSNAV-equipped platoons completed nearly twice the FRAGOs completed by the control platoons.

Force Integration

Finally, military analysts are encouraged to consider the potential effects of POSNAV for the entire force. While Armor combat units, tank crews and platoons, demonstrated significantly better performance with POSNAV, the data also bear on POSNAV's unique contributions to combat service (CS) and combat service support (CSS) operations. With respect to CS, for example, the increased accuracy and speed of POSNAV-equipped commanders' reports of other enemy locations can be directly related to their call for fire (CFF) requests to artillery. Given these improvements in time and accuracy of CFF requests, combat modelers might be able to use this soldier-in-the-loop data base to demonstrate POSNAV's carry-over effects in combat service.

Similarly, the fuel savings previously described clearly result in reduced requirements for this critical combat service support asset. The POSNAV commander's enhanced own location awareness will facilitate linkup with any combat service support elements.

Training Implications of POSNAV

Several training implications of the POSNAV system were identified during the crew and platoon testing. First, both participants' reactions and performance indicate that the tank crews and platoons learned to use the POSNAV system rather quickly. In fact, many of the crews and platoons learned each function after only one or two practice trials.

Tactical Training

Learning to use POSNAV effectively with respect to tactical deployment, however, is a more complex issue. For example, platoon leaders--after receiving a mission OPORD--routinely plan their mission and then issue their plans and control and coordinate all platoon actions. While the route designation function of POSNAV may be readily adapted to specify the platoon course of action, no doctrinal guidelines have been established for exploiting and standardizing tactical utilization.

The vision blocks and sights usage data suggests that future POSNAV training programs should include an emphasis on ensuring that tank commanders can effectively integrate the use of POSNAV into a tactical road march or combat mission. The POSNAV-equipped tank commander cannot compromise his crew members by spending less "quality" time looking out the tank's vision blocks and sights. Both on-board observer ratings and TC self-ratings consistently show that commanders with POSNAV spend less time looking out the tank's vision blocks and sights (VBS) during crew marches and platoon missions than commanders without POSNAV. Although these VBS ratings are subjective, the observer ratings and TC self-ratings, collected independently, were significantly correlated (i.e., $\underline{r}$ =.943, $\underline{p}$=.000).

This result could have implications on the ability of the tank crews and platoons to detect targets, search for firing positions, and maintain command and control. Future POSNAV unit or sustainment training programs should include time for preparing commanders to integrate POSNAV with other mission tasks.

This finding, however, needs to be assessed in a more extended operational training setting. The crews and platoons in this research were given one day of training on the POSNAV display and control features before actual testing began. Crews and platoons routinely equipped with POSNAV may be able to more effectively integrate the use of POSNAV with other critical road march and mission behaviors, including looking out the tank's vision blocks and sights. A longer training program--one which allowed the tank crews and platoons more opportunities to become familiar with the system in more diverse situations--appears especially important in assuring this POSNAV integration.

It should also be noted that the result is based on a relatively imprecise measure of commander's behavior. To avoid having data collectors make inferences, for example, about whether commanders were focusing more on terrain features than enemy units, the data collectors were trained to collect data concerning where the commander was looking, not what he was specifically looking at. Furthermore, these VBS usage ratings do not reflect the effectiveness in which the commanders used their vision blocks and sights. While baseline commanders may have spent more time looking out the tank's vision blocks than the

POSNAV-aided commanders, the POSNAV-aided commanders may have used their vision blocks and sights more effectively. Future research should examine these important, but complex, issues.

Additional POSNAV training time will also assure that tank commanders and other crew members have an opportunity to learn to trust the POSNAV system. The crew members in the current research frequently commented that they initially had to discover that the system actually worked.

Degraded Modes

The crews indicated that critical map reading and land navigation tasks could be performed with less difficulty in SIMNET with POSNAV than they could in the actual tank in the field without POSNAV. These findings are not surprising. POSNAV automates many of these critical tasks for the commander. Nevertheless, future POSNAV trainers should continue to teach basic map reading and land navigation skills. The tank crews must always be prepared for POSNAV system breakdowns or malfunctions. Commanders must learn to rely on POSNAV with some restraint so that they can quickly realize when the system has failed and revert to more traditional means of navigation. Thus, commanders cannot forget how to do polar plots, intersection, resection, and other fundamental map reading skills.

The potential effects of becoming too dependent on the POSNAV system is illustrated by two separate incidents during the crew testing where a commander quickly inputted his route checkpoints and then placed his paper map aside and began the march. Both of these commanders drove directly into an NBC area indicated on their paper map march overlay but not annotated on their POSNAV display. Having never taken the time to examine their map for potential obstacles and appropriate movement routes between checkpoints, these commanders made errors which may have cost them their lives on an actual battlefield.

Duty Specific

The potential reduction in commander workload and the capability of drivers to navigate autonomously raise important training and doctrinal issues. First, tank commander training and experience with POSNAV-equipped tanks must promote their trust of the operational capabilities and reliability of the POSNAV system. Commander's confidence in the system's reliability and in the driver's proficiency in interpreting the POSNAV display and tactically executing the assigned routes should substantially free commanders to shift their attention to other mission critical tasks, such as planning, engaging, and coordinating crew and platoon performance.

The potential for drivers to navigate independently will require revisions to current driver training programs, Armor doctrine, and standard operating procedures (SOPs). Driver training programs should ensure that drivers can clearly comprehend the data provided on the driver's display. Drivers should also be trained to navigate independently for an extended period of time and distance (i.e., between route waypoints). This autonomy is quite unlike the high rates of communications, evidenced by the control data, between the tank commander and driver typical of conventional navigation procedures.

Training should also emphasize the requirements for effective information sharing and coordination of POSNAV waypoint updating between the driver and tank commander. The POSNAV prototypes evaluated did not automatically update the driver's display as waypoints were reached. As waypoint 1 was achieved, for example, the data for waypoint 2 was not automatically directed to the driver's display. Instead, the commander was solely responsible for updating the driver's display with the next waypoint. Users preferred that commanders be left in control of this function. While the data on TC and driver communications show significant reductions, training must ensure that TCs and drivers effectively coordinate their respective duties.

Extended Operations

Finally, the POSNAV system's potential for enhancing the Armor Maneuver Forces' requirements for low visibility (e.g., smoke, night, NBC, fog, closed-hatch) combat operations will have far-ranging training and doctrinal implications across the entire AirLand Battle.

The POSNAV Soldier-Machine Interface

The soldiers indicated strong support for the POSNAV system interface used in the current research. Although some suggestions were offered for improving the display, the soldiers generally believed that the functions were easy to use, that the display was easy to read, and that no trivial or non-useful functions were included on the display. The soldiers frequently expressed praise for the POSNAV system and indicated that they were eager to see a POSNAV display placed in the M1A1 tank.

Overall, the crews offered several suggestions for improving POSNAV. Two suggestions indicated by several of the crews included:

1. Add a system indicator light or acoustic signal to (a) indicate to the tank commander that a route checkpoint has

been received by the driver's POSNAV display and (b) that an entry was inputted incorrectly.

2. Have the POSNAV map display indicate the locations of other friendly elements.

The crews in the POSNAV grid map condition (POSNAV-G) consistently indicated that they would prefer to have the POSNAV map display include terrain features, especially contour lines. The crews in the POSNAV terrain map condition indicated that the contour lines on the POSNAV map display should include elevation indexes to ensure that they can distinguish between hills and depressions.

Generally, the tank crews indicated that all of the POSNAV features were critical or helpful for land navigation, although special emphasis was placed on the helpfulness of the route designation function and the POSNAV map display with own-vehicle icon.

The tank crews were generally satisfied with the training program used in the current research. However, many of the crews suggested that they would have preferred additional training time to "play with the system." Some of the crews who used the POSNAV system indicated that POSNAV training should include performing some exercises navigating without the display. Crews also suggested that unit training on POSNAV would need to include a greater variety of conditions, including night, smoke, and open-hatch.

Reactions to the SIMNET system were generally positive. While some crews were opposed to SIMNET prototype testing because of concerns about SIMNET fidelity and validity, most crews indicated that they believed SIMNET would allow the Army to learn much about the POSNAV system before it is built, particularly with respect to soldier-machine-interface issues. Most of the crews, however, asserted that SIMNET testing should not replace, but instead complement, field prototype testing.

The SIMNET-D Experimental Test Bed

The SIMNET-D test bed provided an excellent opportunity to avoid many of the problems of field research, such as the limited opportunities field research offers for collecting objective, accurate performance measures and for completing many critical, but unsafe, combat mission tasks. SIMNET-D, however, was unable to avoid at least one problem found in field research: equipment breakdowns. The current researchers faced numerous SIMNET-D equipment failures, particularly with the SAF and radios.

For example, during about 50 percent of the platoon missions the SAF simulation system crashed at least once, forcing the researchers to halt platoon testing and reenter all OPFOR and BLUEFOR vehicle parameters and locations. The SAF also did not allow the researchers enough freedom to control vehicle parameters, such as firing accuracy. For example, the OPFOR vehicles can not be set up to shoot but not kill. This feature would be desirable in many experimental situations, such as when a researcher is interested in prompting a critical tank platoon mission task without destroying platoon vehicles. Future efforts should be aimed at improving the reliability of the OPFOR and BLUEFOR simulation, as well as the ability of researchers to more completely standardize and customize OPFOR parameters.

Problems with the radios used in the SIMNET-D modules and company commander's stations also resulted in frequent interruptions during the current research. Many of these errors could be attributed to the inability of the soldiers to fully learn to appropriately use the SIMNET radios. SIMNET radio interfaces are different from, and probably less reliable than, those used in real tanks. Higher fidelity radios should prove more reliable and require less tanker training time to use.

It should be noted that while SIMNET-D equipment breakdowns may have been as frequent as those which occur in the field, they certainly did not take as much time to fix. In many cases, these breakdowns resulted in a disturbance of only a few moments. These breakdowns, however, placed additional stress on both the soldiers and the research staff.

In addition to SIMNET-D equipment breakdowns, DataProbe software proved unable to currently support the quick turn around of results often necessary in combat development research. For example, DataProbe programs--written jointly by the first author and a SIMNET-D BBN analyst--could run over thirty hours to analyze a single two-and-a-half hour mission exercise. A typical one-and-a-half hour road march exercise took about six hours to analyze.

The primary cause of this excess analysis time was in providing overall performance measures from voluminous continuous data, such as movement speed and distance travelled. This excessive analysis time was compounded by occasional DataProbe system crashes, which forced the researchers to reanalyze several road march and mission runs. Future efforts should be dedicated to developing more automated, reliable, and real-time SIMNET performance measurement capabilities.

The original design philosophy of SIMNET emphasized training and particularly the opportunity to repeatedly and realistically practice military operation in a nonevaluative setting. Establishment of the SIMNET-D test bed is requiring a reconsideration of this philosophy and the provision of the test bed resources required for formal evaluations, including: (a) instrumentation of the combat development systems under investigation; (b) automated crew functions, such as an automatic loader, to reduce personnel requirements; (c) more standardized SAF parameters; (d) batch initialization of manned and semi-automated systems; (e) synchronized audio and digital recording; and (f) reformulation of data protocols and sampling rates.

SIMNET-D is a relatively new Army test bed. The current test is the longest and most resource-demanding experiment conducted to date in SIMNET-D. With a greater commitment to the developmental test bed philosophy and with more feedback from users, SIMNET-D will become an even more effective laboratory for the Army to test and evaluate developmental systems.

Summary and Conclusions

Overall, the current research strongly suggests that POSNAV will significantly improve the performance of tank crews and platoons. Crews and platoons with POSNAV completed road marches and combat missions in a simulated battlefield setting more effectively on 32 of 36 performance measures evaluated than crews and platoons without POSNAV. The methodology as described, we believe, provides an internally valid basis for substantiating the potential impact of POSNAV on small unit performance.

Two important limitations of the current effort must be noted, however, with respect to the external validity of these findings. First, the current research findings hinge strongly on the relationship between crew and platoon performance in SIMNET and in the real world. This relationship has yet to be completely validated.

Second, the current research did not use intact crews and platoons. Instead, collections of qualified soldiers were assigned to tank crews and platoons. Nevertheless, non-intact crew and platoon arrangements may better represent the force mobilization and combat attrition demands common to the Armor Force in war.

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Appendix A

Map Overlays for Crew Tactical Road Marches: Crew Road March Alpha, Bravo, and Delta

Figure A-1

Map Overlay for Crew Tactical Road March Alpha

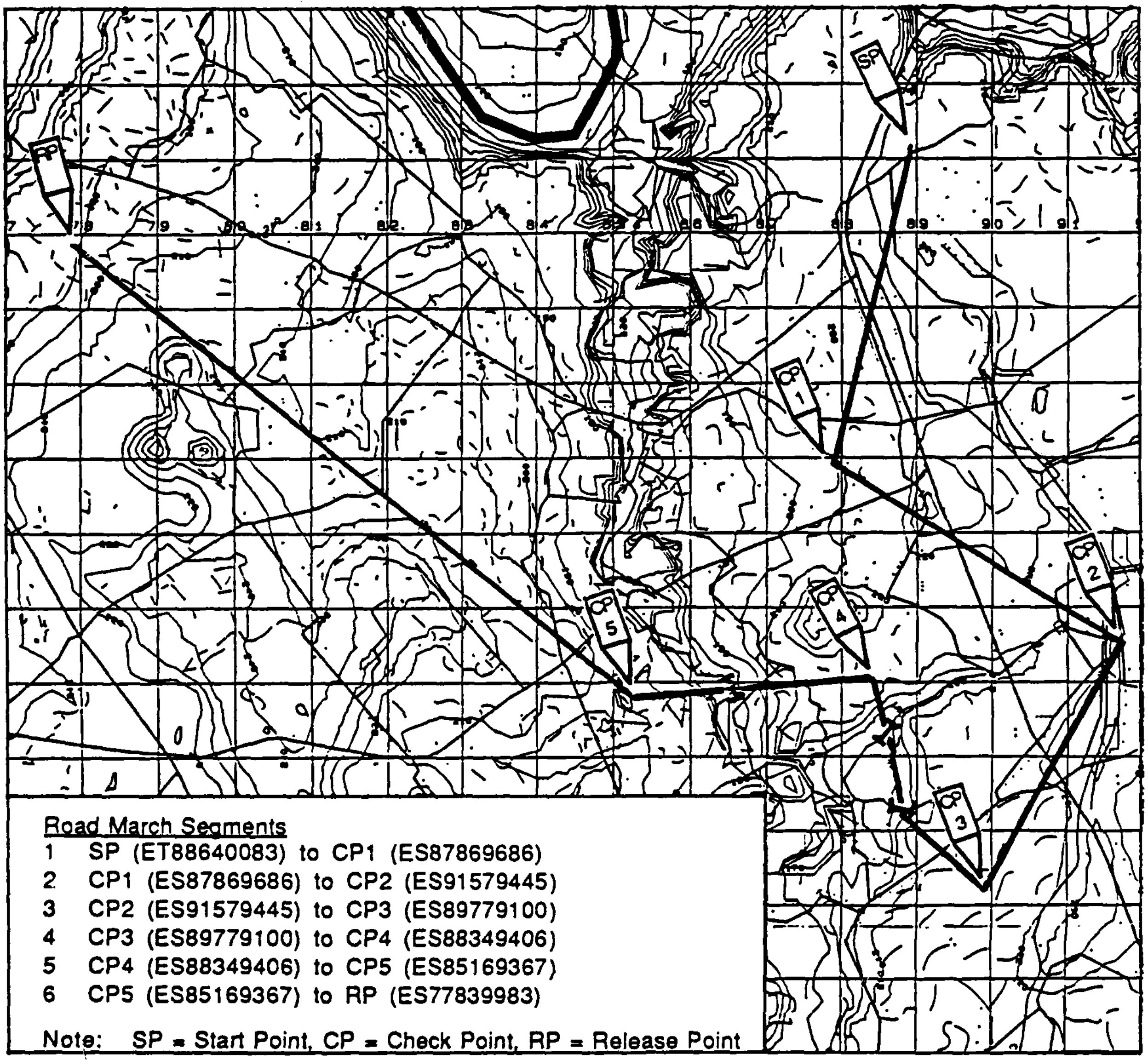

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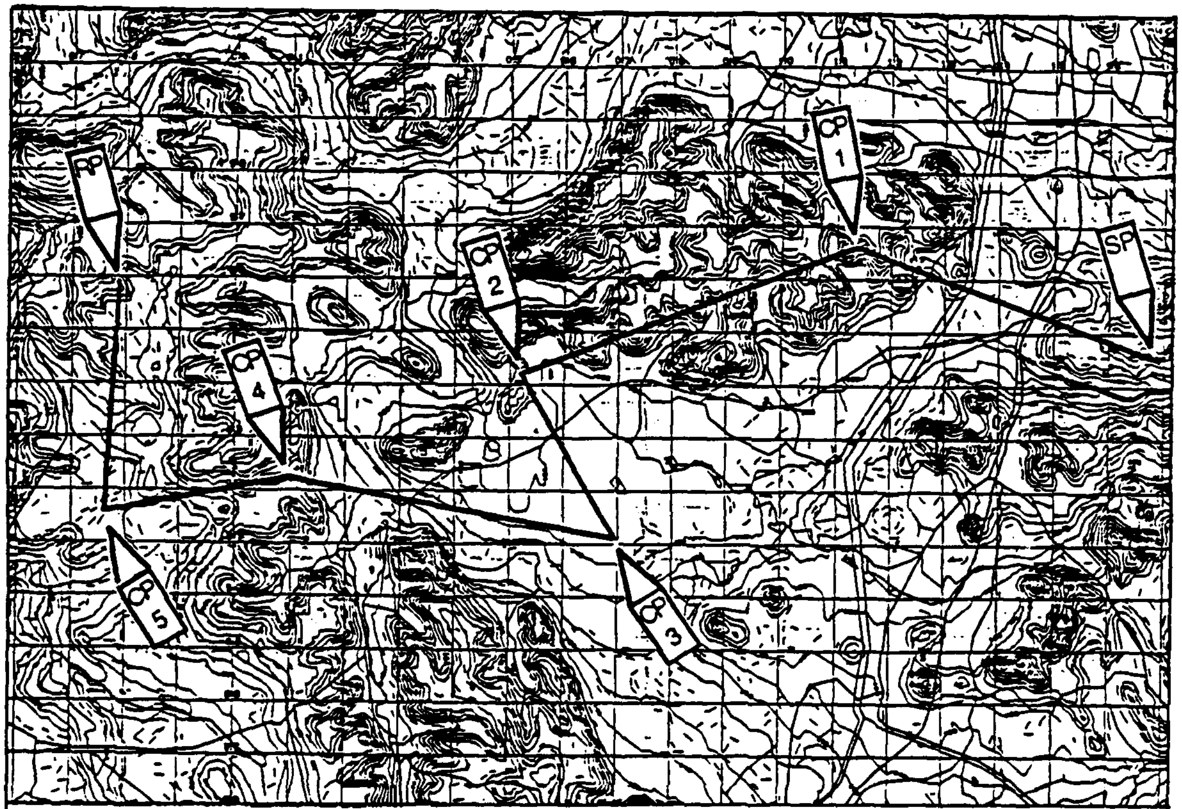
Figure A-2

Map Overlay for Crew Tactical Road March Bravo



Road March Segments

1 SP (FS16979442) to CP1 (FS11259658)
2 CP1 (FS11259658) to CP2 (FS05149409)
3 CP2 (FS05149409) to CP3 (FS068[illegible])
4 CP3 (FS06899109) to CP4 (FS009[illegible])
5 CP4 (FS00999226) to CP5 (ES97649[illegible])
6 CP5 (ES97649161) to RP (ES97849592)

Note: SP = Start Point, CP = Check Point, RP = Release Point

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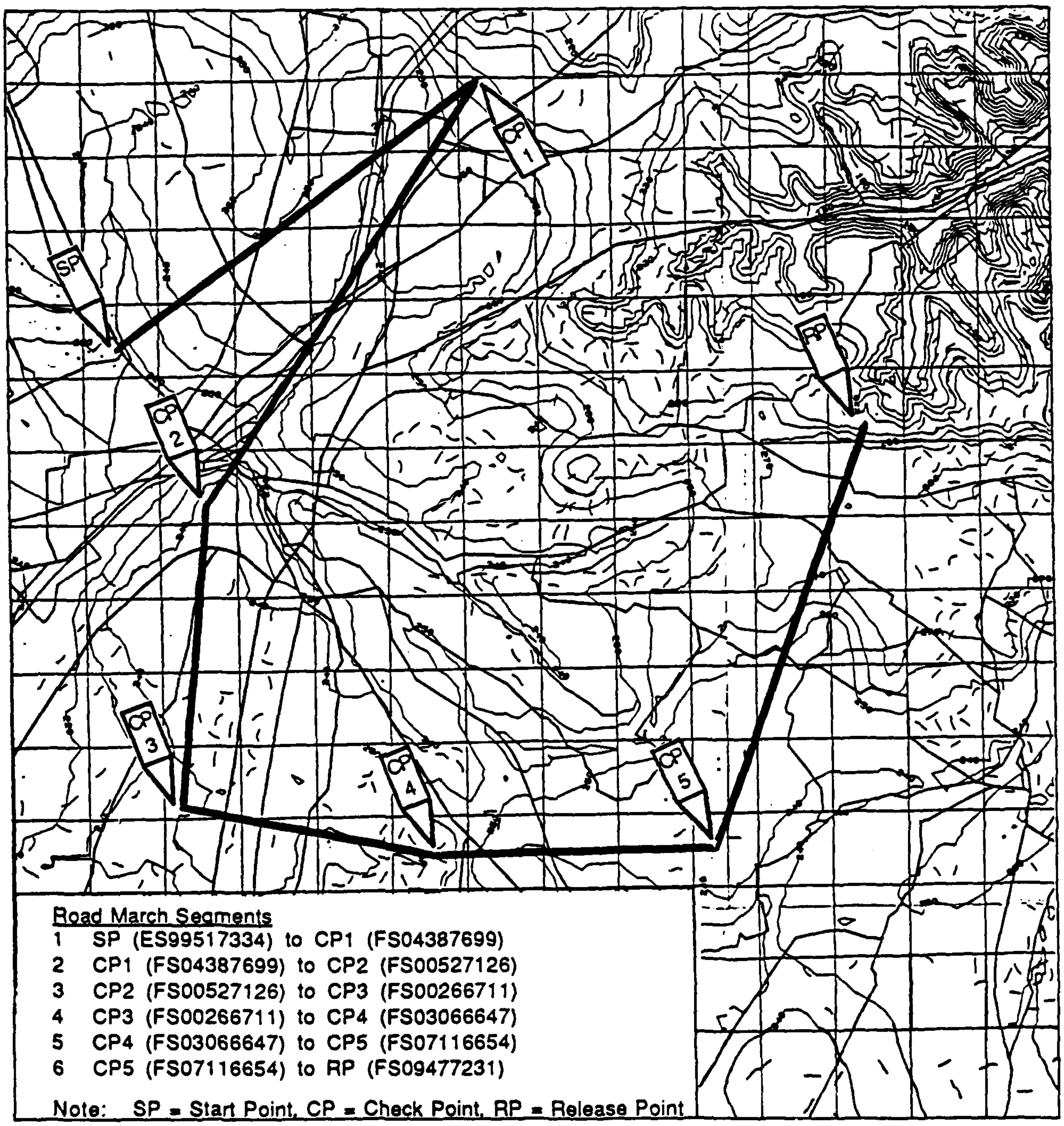
Figure A-3

Map Overlay for Crew Tactical Road March Delta



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Appendix B

Questionnaires Used in the Current Experiment:
Biographical Questionnaire, Task Difficulty Questionnaire,
POSNAV SMI Questionnaire, and Land Navigation Skills Test

Name ______________________

SSN ______________________

Date ______________________

Ss #________

Tank #______

(for experimenter use only)

BIOGRAPHICAL QUESTIONNAIRE

1. AGE: _______ years

2. CURRENT ARMY GRADE: E-____ or O-____

3. EDUCATIONAL LEVEL (circle one):

   a. less than 12 years
   b. GED
   c. high school graduate
   d. technical school graduate
   e. some college (_____ years)
   f. college graduate (degree: ___________)
   g. other (please specify: _________________________)

4. TOTAL TIME IN SERVICE: ENLISTED? ____ years ___ months

   COMMISSIONED? ____ years ___ months

5. TOTAL TIME IN ARMOR UNITS: _____ years _____ months

6. MOS LEVEL: MOS-______-____

7. PRESENT TANK DUTY POSITION (circle one):

   a. tank driver
   b. tank commander (TC)
   c. platoon seargent (PS)
   d. platoon leader (PL)

8. EXPERIENCE AS A TANK DRIVER: _____years _____months

9. EXPERIENCE AS A TANK COMMANDER:
   (Do Not include time spent as
   a Plt Leader or Plt Seargent)
   _____years _____months

PT5751

10. EXPERIENCE AS A TANK PLATOON LEADER:

_____years _____months

11. EXPERIENCE AS A TANK PLATOON SEARGENT:

_____years _____months

12. FORMAL TANKER MILITARY COURSES COMPLETED
(check all that apply):

___AIT/OSUT ___TANK COMMANDER COURSE ___MASTER GUNNER COURSE

___BNCOC ___ANCOC ___AOBC ___AOAC

___Other (please describe: ______________________________

____)

13. TIME SINCE LAST PARTICIPATED IN A FIELD TRAINING/SUSTAINMENT EXERCISE (excluding National Training Center exercises) AS A TANKER:

_______months.

14. NUMBER OF TIMES PARTICIPATED AS A TANKER IN NATIONAL TRAINING CENTER EXERCISES: ______times

a. When was the last time? ___________

b. What was you tank duty position at that time? _______________

15. NUMBER OF HOURS PREVIOUSLY SPENT ON SIMNET: ______hours

a. Hours spent on SIMNET at your current tank duty position: ______hours

b. Time since last operated in SIMNET: ______months

16. IN GENERAL, HOW WOULD YOU DESCRIBE YOUR PREVIOUS EXPERIENCE WITH COMPUTERS? (check one)

___No Experience (Never use computers) ___Limited Experience (Rarely use computers) ____Some Experience (Occasionally use computers) ____Considerable Experience (Frequently use computers)

PT5751

NAME________________ Ss #__________

DATE________________ TANK #________

C A B

FOR EXPERIMENTER USE ONLY

TC FEEDBACK/DEBRIEF QUESTIONNAIRE

Now that you have completed the road march and mission exercises in SIMNET, we would like you to rate the difficulty of performing basic land navigation tasks. First, we ask that you rate the difficulty of performing basic land navigation tasks in SIMNET. Second, we ask that you rate the difficulty of performing basic land navigation tasks in the field in an actual tank.

Think about your overall performance in the crew road marches and platoon mission exercises, focusing especially on your <u>overall</u> performance in completing the following land navigation tasks:

1. Determining your own tank grid location;
2. Determining your own tank orientation;
3. Maintaining your own tank orientation;
4. Determining the location of other objects (e.g., for spot reports);
5. Navigating from one location to another;
6. Maintaining platoon formation;
7. Performing map-terrain association;
8. Bypassing obstacles (e.g., NBC areas); and,
9. Reorienting after reaction to enemy fire (e.g., air and artillery strikes).

For each of the nine land navigation tasks identified above, please complete two ratings. First, rate the difficulty you experienced during this experiment performing each task. Begin by deciding whether the land navigation task was easy or difficult in SIMNET. Then indicate how difficult or how easy each of these tasks were and circle the appropriate rating.

Second, rate the difficulty you believe you would experience, based on your field experiences, doing each task in similar marches and missions in an actual tank. Begin by deciding whether the land navigation task would be easy or difficult in an actual tank. Then indicate how difficult or how easy each of these tasks are and circle the appropriate rating.

Write any comments regarding why you chose each rating in the space provided.

PT5750

LAND NAVIGATION TASKS	Task Difficulty in SIMNET							Task Difficulty in Actual Tank							COMMENTS
	Easy Task ---------- Difficult Task							Easy Task ---------- Difficult Task							Write additional comments on back of page.
	Extremely Easy 1	Quite 2	Slightly 3	Neutral 4	Slightly 5	Quite 6	Extremely Difficult 7	Extremely Easy 1	Quite 2	Slightly 3	Neutral 4	Slightly 5	Quite 6	Extremely Difficult 7	
1. Determining your own tank grid location.	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1
2. Determining your own tank orientation.	1	2	3	4	5	6	7	1	2	3	4	5	6	7	2
3. Maintaining your own tank orientation.	1	2	3	4	5	6	7	1	2	3	4	5	6	7	3
4. Determining the grid location of other objects (e.g., spot reports).	1	2	3	4	5	6	7	1	2	3	4	5	6	7	4
5. Performing Map-Terrain Association.	1	2	3	4	5	6	7	1	2	3	4	5	6	7	5
6. Navigating from one point to another.	1	2	3	4	5	6	7	1	2	3	4	5	6	7	6
7. Maintaining platoon formation.	1	2	3	4	5	6	7	1	2	3	4	5	6	7	7
8. Bypassing obstacles (e.g., NBC areas).	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8
9. Reorienting after reaction to enemy fire (e.g., air or artillery strikes).	1	2	3	4	5	6	7	1	2	3	4	5	6	7	9

PT5750

NAME ____________
DATE ____________

POSNAV QUESTIONNAIRE

PART I

We would like to get your expert opinion on issues specific to the POSNAV system. Please indicate your agreement/disagreement with each of the items below using the five-point rating scale provided above. Write the number of your rating in the space provided after each item. Your ratings will be very important in helping us to evaluate the effectiveness of the POSNAV system, as well as to determine any necessary modifications which need to be made to POSNAV to make it a more effective aid for tankers.

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

1. The location of the POSNAV TC's display in the M1 simulator was acceptable. ______
2. I could easily navigate from one point to another using only the POSNAV Driver's "Steer-to" display. ______
3. When navigating, the POSNAV map automatically scrolls at an acceptable rate. ______
4. The POSNAV map at the 1:25,000 scale (about 3 km by 3 km) is difficult to read. ______
5. The POSNAV map at the 1:50,000 scale (about 5 km by 5 km) is difficult to read. ______
6. The POSNAV map at the 1:125,000 scale (about 11 km by 11 km) is difficult to read. ______
7. I could easily read the information on the POSNAV display. ______

PT5753

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

8. The touch screen was easy to use to select POSNAV menu options. ______

9. The POSNAV display is too small. ______

10. The location of the POSNAV "Own Location" window is acceptable. ______

11. The location of the POSNAV "Main Menu" is acceptable. ______

12. The POSNAV "Route Designation" function is easy to use. ______

13. The POSNAV map is more helpful for navigating in SIMNET than a paper map. ______

14. I rarely used my paper map for navigating. ______

15. I spent more time looking at the POSNAV display than I did looking through the vision blocks and sights. ______

16. I spent more time looking at the POSNAV display than I tactically should have. ______

17. I gave the driver more control over the navigation of the tank than I would have without the POSNAV display. ______

18. I spent less time communication with the driver than I would have without the POSNAV display. ______

19. The POSNAV tank icon was useful for orienting my tank in the proper direction. ______

20. The MAP "Zoom" function was easy to use. ______

21. The MAP "Features" function was difficult to use. ______

PT5753

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree

22. I rarely changed the scale of the POSNAV map. ______

23. I frequently changed the terrain features which appeared on the POSNAV map. ______

24. The POSNAV map "Scroll-Type In" function was easy to use. ______

25. When navigating the current own-vehicle location update rate of every 10 meters is acceptable. ______

26. The POSNAV display functions were difficult to use while on the move. ______

27. The POSNAV display information was difficult to read while on the move. ______

28. With POSNAV, I had more time to acquire enemy targets. ______

29. The POSNAV system replaces the need for a compass for land navigation. ______

30. I could easily enter waypoint grid coordinates for the POSNAV "Route Designation" function. ______

31. I had a difficult time changing or deleting POSNAV "Route Designation" waypoint entries. ______

32. I could easily send waypoint data to the POSNAV Driver's "Steer-to" display. ______

33. The POSNAV map "Zoom" function was easy to use. ______

34. POSNAV waypoint updating should be under the driver's control. ______

PT5753

PART II

Now that you have responded to a series of very specific items, we want to get your general impressions and thoughts about the POSNAV system and this experiment. Please answer each question below as carefully and completely as possible. Remember, every bit of information you give will be critical in helping us 1) to determine the effectiveness of the POSNAV system, and 2) to determine any necessary modifications which need to be made to POSNAV to make it a more effective aid for tankers.

1. *What suggestions could you offer for improving the POSNAV system?*

2. *What features of the POSNAV system were most helpful or critical for land navigation?*

PT5753

3. *Now that you have used POSNAV during this testing, what suggestions could you offer for future POSNAV training programs?*

4. *What do you think about evaluating combat system prototypes first in SIMNET? Are tests like the current one appropriate for predicting how well new tank subsystems, such as POSNAV, will improve crew and platoon performance?*

PT5753

5. *List below any other comments/suggestions you would like to offer about the POSNAV system or the current testing effort?*

PT5753

LAND NAVIGATION SKILLS TEST

INSTRUCTIONS

This test is designed to assess those skills which are necessary to effectively navigate in a SIMNET environment. This test contains 18 questions requiring free response. Please read each question carefully and write your answers on the answer sheet provided. You have a SIMNET SPECIAL MAP, pencil, marker, protractor, and scratch paper for use in completing this test. When you finish, bring your test materials to one of the test administrators. If you should have any questions about a particular test item while completing this exam, please feel free to ask one of the test administrators.

PT5749

LAND NAVIGATION SKILLS TEST

SITUATION A: You are a tank commander in Co A, 2d Bn, 24th Armor. You are currently located at ES793971. Answer the following questions.

1. What natural terrain feature are you currently located on?

2. What is the elevation in meters of your current own-tank location?

3. What type of road is closest to your current own-tank location, a paved or unpaved road?

4. The combat trains are located at grid ES80859130. From your current location and disregarding any tree-lines or man-made structures, do you have a direct line of sight to the combat trains location?

5. Your battalion commander is located 4910 meters from your location on a mil azimuth of 1720 mils. What is the six-digit grid coordinate of your battalion commander's location?

6. Given an order, you move from your present location to a road junction at grid ES85279195. What is the straight line distance in meters from your previous location (ES793971) to your new location (ES85279195)?

7. What is the azimuth heading in mils from your previous location (ES793971) to your new location at grid ES85279195?

8. If your tank odometer reading at the start of movement was 0842[0] and you moved in a straight line from your previous location (ES793971) to your new location (ES85279195), what would your tank odometer reading be when you reached your new location?

PT5749

LAND NAVIGATION SKILLS TEST

SITUATION B: Your platoon is defending in sector. You have relocated to a battle position located at grid ES880950. Answer the following questions.

1. What natural terrain feature are you currently located on?

2. What is the eight-digit grid coordinate of the man-made structure closest to your current own-tank location?

3. What is the elevation in meters of your current own-tank location?

4. You identify enemy vehicles at an azimuth of 5590 mils from your location. After lasing to the enemy location, you determine your distance from the enemy vehicles to be 3100 meters. What is the six-digit grid coordinate of the enemy location?

5. If you were to travel in a straight line from your present location (ES880950) to the enemy location and your tank odometer reading at movement start was 9111/1, what would your tank odometer reading be when you reached the enemy grid location?

6. The combat trains are located at ES898941. What is the back azimuth heading in mils from your current location at ES880950 to the trains?

PT5749

LAND NAVIGATION SKILLS TEST

SITUATION C: Your platoon has just completed an intense battle with an enemy company. Unsure of your exact grid location, you identify a bridge that you know to be at grid ES874860. Answer the following questions.

1. You determine the azimuth heading from your own-tank location to the bridge to be 1540 mils. What is the back azimuth heading <u>in mils</u> from your location to the bridge?

2. You lase to the bridge and determine the range to be 2980 meters. What is the six-digit grid coordinate of your current location?

3. Name and give the number of all terrain features, both man-made and natural, located in grid square ES8990.

4. What is the contour interval of the SIMNET SPECIAL MAP you are currently using?

PT5749

Appendix C

Soldier Data by Test Condition and Tank Position: Means, Standard Deviations, and MANOVA Analyses

Table C-1

Soldier Data Means and Standard Deviations for POSNAV-G Test Condition

Measure		Tank Position					
		Overall	Platoon Leader	Platoon Sergeant	TC	Driver	Gunner
TANKTIME	M	52.47	6.60	120.80	81.80	29.45	55.20
	SD	51.20	3.91	56.50	37.67	19.93	59.96
	N	60	5	5	10	20	20
JOB_EXP	M	18.72	4.20	51.40	32.90	8.00	17.80
	SD	25.22	3.63	32.14	26.38	19.38	22.04
	N	60	5	5	10	20	20
NTCCOUNT	M	.59	.00	.80	.80	.32	.84
	SD	.77	.00	1.10	.79	.48	.90
	N	58	5	5	10	19	19
CO	M	110.54	*	109.80	112.44	111.25	109.00
	SD	11.59		17.34	10.67	12.14	10.44
	N	52		5	9	20	18
GT	M	109.26	*	114.20	112.67	107.45	108.26
	SD	11.93		18.25	8.12	13.52	9.88
	N	53		5	9	20	19
LNTSCORE	M	10.43	15.80	12.80	14.00	7.95	9.20
	SD	5.11	1.64	2.17	4.08	4.62	5.14
	N	60	5	5	10	20	20
SIM_EXP	M	9.08	8.80	10.80	4.20	13.65	6.60
	SD	16.34	12.46	14.94	5.05	23.35	12.28
	N	60	5	5	10	20	20
COMP_EXP	M	2.27	3.00	1.60	2.00	2.30	2.35
	SD	.94	1.00	.89	.94	.92	.88
	N	60	5	5	10	20	20

* Platoon Leaders are not required to complete the ASVAB.

Note: TANKTIME is number of months in Armor. JOB_EXP is number of months at test tank position. NTCCOUNT is number of times at Army National Training Center. CO is ASVAB Combat Orientation score. GT is ASVAB General Technical score. LNTSCORE is Land Navigation Skills Test score. SIM_EXP is number of hours previously spent on SIMNET. COMP_EXP is a self-reported rating of computer experience on a four-point scale (i.e. 1 = no experience, 2 = limited experience, 3 = some experience, 4 = considerable experience). M is the mean, SD is the standard deviation, and N is the number of valid observations.

Table C-2

Soldier Data Means and Standard Deviations for POSNAV-T Test Condition

Measure		Tank Position					
		Overall	Platoon Leader	Platoon Sergeant	TC	Driver	Gunner
TANKTIME	M	55.28	3.00	121.20	90.60	36.75	52.75
	SD	46.09	2.24	42.90	39.76	31.77	39.52
	N	60	5	5	10	20	20
JOB_EXP	M	20.63	.20	35.60	34.80	10.35	25.20
	SD	25.30	.45	25.43	25.11	13.25	31.14
	N	60	5	5	10	20	20
NTCCOUNT	M	.49	.00	1.40	.40	.30	.63
	SD	.88	.00	2.19	.70	.47	.76
	N	59	5	5	10	20	19
CO	M	110.30	*	123.00	107.60	113.95	105.45
	SD	12.51		13.37	10.11	13.10	10.56
	N	54		4	10	20	20
GT	M	107.27	*	109.40	102.10	111.55	105.05
	SD	12.91		9.79	11.66	14.99	11.18
	N	55		5	10	20	20
LNTSCORE	M	11.57	15.20	14.80	10.80	11.05	10.75
	SD	4.02	1.92	3.27	3.39	4.24	4.02
	N	60	5	5	10	20	20
SIM_EXP	M	5.47	3.20	15.00	2.30	6.40	4.30
	SD	11.65	2.95	25.99	3.40	13.32	7.85
	N	60	5	5	10	20	20
COMP_EXP	M	2.33	3.40	2.40	1.90	2.15	2.45
	SD	.99	.89	1.14	.88	.99	.89
	N	60	5	5	10	20	20

* Platoon Leaders are not required to complete the ASVAB.

Note: TANKTIME is number of months in Armor. JOB_EXP is number of months at test tank position. NTCCOUNT is number of times at Army National Training Center. CO is ASVAB Combat Orientation score. GT is ASVAB General Technical score. LNTSCORE is Land Navigation Skills Test score. SIM_EXP is number of hours previously spent on SIMNET. COMP_EXP is a self-reported rating of computer experience on a four-point scale (i.e. 1 = no experience, 2 = limited experience, 3 = some experience, 4 = considerable experience). M is the mean, SD is the standard deviation, and N is the number of valid observations.

Table C-3

Soldier Data Means and Standard Deviations for POSNAV-C Test Condition

Measure		Tank Position					
		Overall	Platoon Leader	Platoon Sergeant	TC	Driver	Gunner
TANKTIME	M	63.30	18.60	120.80	98.60	36.00	69.75
	SD	52.41	21.36	61.63	42.45	30.19	5[illegible].68
	N	60	5	5	10	20	20
JOB_EXP	M	25.65	3.00	46.80	64.20	8.05	24.35
	SD	31.75	6.71	30.64	41.26	15.47	22.70
	N	60	5	5	10	20	20
NTCCOUNT	M	.67	.20	.60	.80	.80	.60
	SD	1.20	.45	.55	.92	1.79	.82
	N	60	5	5	10	20	20
CO	M	107.87	*	114.50	104.10	106.37	109.85
	SD	14.30		10.63	11.85	15.37	15.14
	N	53		4	10	19	20
GT	M	106.61	*	110.60	104.50	105.84	107.40
	SD	11.38		14.91	10.21	10.16	12.62
	N	54		5	10	19	20
LNTSCORE	M	10.77	15.20	11.40	10.60	9.40	10.95
	SD	4.03	2.77	1.14	2.59	4.43	4.30
	N	60	5	5	10	20	20
SIM_EXP	M	12.22	22.40	3.20	17.80	10.90	10.45
	SD	23.71	43.48	4.38	31.13	18.97	21.32
	N	60	5	5	10	20	20
COMP_EXP	M	2.32	3.00	2.60	2.60	2.10	2.15
	SD	.99	1.00	1.52	1.08	.85	.93
	N	60	5	5	10	20	20

* Platoon Leaders are not required to complete the ASVAB.

Note: TANKTIME is number of months in Armor. JOB_EXP is number of months at test tank position. NTCCOUNT is number of times at Army National Training Center. CO is ASVAB Combat Orientation score. GT is ASVAB General Technical score. LNTSCORE is Land Navigation Skills Test score. SIM_EXP is number of hours previously spent on SIMNET. COMP_EXP is a self-reported rating of computer experience on a four-point scale (i.e. 1 = no experience, 2 = limited experience, 3 = some experience, 4 = considerable experience). M is the mean, SD is the standard deviation, and N is the number of valid observations.

Table C-4

Omnibus MANOVA Tests for Selected Soldier Data

Interaction: Test Group by Tank Position

Test	Value	Approx F	Hyp df	Err df	p
Pillais V	.31465	1.121	48	972.00	.269
Hotellings	.34479	1.116	48	932.00	.276
Wilk's lambda	.71953	1.119	48	776.57	.272
Roy's GCR	.13060				

Main Effect: Test Group

Test	Value	Approx F	Hyp df	Err df	p
Pillais V	.06814	.929	12	316.00	.518
Hotellings	.07124	.926	12	312.00	.512
Wilk's lambda	.93271	.928	12	314.00	.519
Roys GCR	.05174				

Main Effect: Tank Position

Test	Value	Approx F	Hyp df	Err df	p
Pillais V	.64855	5.160	24	640.00	.000
Hotellings	.96332	6.241	24	622.00	.000
Wilk's lambda	.45760	5.745	24	548.92	.000
Roy's GCR	.39999				

Note: Selected soldier data includes TANKTIME, JOB_EXP, NTCCOUNT, LNTSCORE, SIM_EXP, and COMP_EXP.Test groups include POSNAV-G, POSNAV-T, and POSNAV-C. Tank positions include platoon leader, platoon sergeant, tank commander, driver, and gunner.

Table C-5

Summary of Univariate ANOVAs with (4,162) D.F.s and Tukey Tests for the Tank Position Main Effect

Measure	Treatment MS	Error MS	*F*	*p*	Tukey CV
TANKTIME	1177.893	1705.858	23.481	.000	49.80
JOB_EXP	9500.972	554.661	17.129	.000	29.19
NTCCOUNT	1.864	.931	2.002	.097	1.18
LNTSCORE	132.204	16.630	7.950	.000	5.07
SIM_EXP	124.307	124.307	.374	.827	22.43
COMP_EXP	3.087	.880	3.507	.009	1.17

Note: Tank positions include platoon leader, platoon sergeant, tank commander, driver, and gunner. Tukey Honestly Significant test critical values based on alpha = .05.

Table C-6

Omnibus MANOVA Tests for Soldier ASVAB Scores: Combat Orientation (CO) and General Techical (GT)

Interaction: Test Group by Tank Position

Test	Value	Approx F	Hyp df	Err df	p
Pillais V	.09078	1.16493	12	294.00	.308
Hotellings	.09524	1.15077	12	290.00	.319
Wilk's lambda	.91122	1.15786	12	292.00	.313
Roy's GCR	.05319				

Main Effect: Test Group

Test	Value	Approx F	Hyp df	Err df	p
Pillais V	.03496	1.30751	4	294.00	.267
Hotellings	.03588	1.30059	4	290.00	.270
Wilk's lambda	.96521	1.30409	4	292.00	.269
Roys GCR	.02940				

Main Effect: Tank Position

Test	Value	Approx F	Hyp df	Err df	p
Pillais V	.03460	.86274	6	294.00	.523
Hotellings	.03574	.86367	6	290.00	.522
Wilk's lambda	.96545	.86325	6	292.00	.522
Roy's GCR	.03307				

Note: Test groups include POSNAV-G, POSNAV-T, and POSNAV-C. Tank positions include platoon sergeant, tank commander, driver, and gunner. Platoon leaders are not required to complete the ASVAB. CO is ASVAB Combat Orientation score. GT is ASVAB General Technical score.

Appendix D

Crew Road March Analyses:
Correlation Matrix,
Univariate Tests of Homogeneity of Variance,
and Discriminant Analysis Findings

Table D-1

Correlation Matrix for Crew Road March
Measures of Effectiveness

		RUNTIME	PLANTIME	CPDEV	LRDEV	LRTIME	NBC	DISTANCE	FUEL
RUNTIME	r	1.000	.573	.786	.682	.873	-.367	.445	.513
	p	-	.000	.000	.000	.000	.004	.000	.000
PLANTIME	r	.573	1.000	.581	.649	.498	-.298	.593	.630
	p	.000	-	.000	.000	.000	.021	.000	.000
CPDEV	r	.786	.581	1.000	.720	.696	-.329	.652	.633
	p	.000	.000	-	.000	.000	.010	.000	.000
LRDEV	r	.682	.649	.720	1.000	.661	-.207	.569	.599
	p	.000	.000	.000	-	.000	.113	.000	.000
LRTIME	r	.873	.498	.696	.661	1.000	-.261	.408	.516
	p	.000	.000	.000	.000	-	.044	.001	.000
NBC	r	-.367	-.298	-.329	-.207	-.261	1.000	-.107	-.198
	p	.004	.021	.010	.113	.044	-	.416	.130
DISTANCE	r	.445	.593	.652	.569	.408	-.107	1.000	.886
	p	.000	.000	.000	.000	.001	.416	-	.000
FUEL	r	.513	.630	.633	.599	.516	-.198	.886	1.000
	p	.000	.000	.000	.000	.000	.130	.000	-
VEL	r	-.941	-.545	-.654	-.584	-.838	.354	-.284	-.379
	p	.000	.000	.000	.000	.000	.006	.028	.003
MOVE	r	-.594	-.152	-.375	-.235	-.276	.143	-.033	.017
	p	.000	.245	.003	.070	.033	.276	.802	.897
PCT0	r	.910	.612	.649	.628	.928	-.359	.340	.481
	p	.000	.000	.000	.000	.000	.005	.008	.000
TCCOM	r	.628	.548	.602	.547	.614	-.266	.572	.571
	p	.000	.000	.000	.000	.000	.040	.000	.000
DVRCOM	r	.441	.584	.497	.324	.249	-.326	.512	.418
	p	.000	.000	.000	.012	.055	.011	.000	.001
PCTVBS	r	.619	.364	.558	.498	.656	-.304	.315	.354
	p	.000	.004	.000	.000	.000	.018	.014	.005
PCTMAP	r	.672	.634	.566	.485	.680	-.194	.325	.399
	p	.000	.000	.000	.000	.000	.138	.011	.002

Note: All probabilities are two-tailed.

Table D-1 (continued)

Correlation Matrix for Crew Road March
Measures of Effectiveness

		VEL	MOVE	PCT0	TCCOM	DVRCOM	PCTVBS	PCTMAP
RUNTIME	r	-.941	-.594	.910	.628	.441	.619	.672
	p	.000	.000	.000	.000	.000	.000	.000
PLANTIME	r	-.545	-.152	.612	.548	.584	.364	.634
	p	.000	.245	.000	.000	.000	.004	.000
CPDEV	r	-.654	-.375	.649	.602	.497	.558	.566
	p	.000	.003	.000	.000	.000	.000	.000
LRDEV	r	-.584	-.235	.628	.547	.324	.498	.485
	p	.000	.070	.000	.000	.012	.000	.000
LRTIME	r	-.838	-.276	.928	.614	.249	.656	.680
	p	.000	.033	.000	.000	.055	.000	.000
NBC	r	.354	.143	-.359	-.266	-.326	-.304	-.194
	p	.006	.276	.005	.040	.011	.018	.138
DISTANCE	r	-.284	-.033	.340	.572	.512	.315	.325
	p	.028	.802	.008	.000	.000	.014	.011
FUEL	r	-.379	.017	.481	.571	.418	.354	.399
	p	.003	.897	.000	.000	.001	.005	.002
VEL	r	1.000	.652	-.923	-.596	-.344	-.582	-.649
	p	-	.000	.000	.000	.007	.000	.000
MOVE	r	.652	1.000	-.341	-.268	-.222	-.212	-.249
	p	.000	-	.008	.039	.089	.104	.055
PCT0	r	-.923	-.341	1.000	.615	.323	.641	.734
	p	.000	.008	-	.000	.012	.000	.000
TCCOM	r	-.596	-.268	.615	1.000	.579	.513	.510
	p	.000	.039	.000	-	.000	.000	.000
DVRCOM	r	-.344	-.222	.323	.579	1.000	.162	.410
	p	.007	.089	.012	.000	-	.217	.001
PCTVBS	r	-.582	-.212	.641	.513	.162	1.000	.358
	p	.000	.104	.000	.000	.217	-	.005
PCTMAP	r	-.649	-.249	.734	.510	.410	.359	1.000
	p	.000	.055	.000	.000	.001	.005	-

Note: All probabilities are two-tailed.

Table D-2

Univariate Tests of Homogeneity of Variance for Crew Road March Measures of Effectiveness

Measure	Cochran's C	p	Bartlett-Box	p
RUNTIME	.75589	.000	12.31762	.000
PLANTIME	.60225	.005	4.66395	.010
CPDEV	.99628	.000	88.22559	.000
LRDEV	1.00000	.000	246.12840	.000
LRTIME	.99239	.000	74.36834	.000
NBC	.57143	.015	3.20146	.041
DISTANCE	.91778	.000	32.15010	.000
FUEL	.76992	.000	14.80456	.000
VEL	.43101	.406	1.11616	.328
MOVE	.61947	.003	4.72388	.009
PCT0	.56455	.018	4.12165	.016
TCCOM	.83094	.000	17.26623	.000
DVRCOM	.76532	.000	11.70496	.000
PCTVBS	.53777	.039	3.45701	.032
PCTMAP	.50204	.097	1.91313	.148

Table D-3

Discriminant Analysis Eigenvalues and Measures of Importance for Crew Road March Measures

Cannonical Discriminant Function	Eigenvalue	Percent of Variance	Cumulative Percentage	Cannonical Correlation
1	21.6421	97.98	97.98	.9777
2	.4471	2.02	100.00	.5559

Derived Function	Wilk's Lambda	Chi-Square	DF	p
0	.0305	174.47	30	.0000
1	.6910	18.48	14	.1858

Table D-4

Discriminant Function Coefficients and Pooled-Within-Groups Correlations for Crew Road March Measures of Effectiveness

Measure	Standardized Cannonical Discriminant Function Coefficients		Pooled-Within-Groups Correlations Between Measures and Cannonical Discriminant Functions	
	Function 1	Function 2	Function 1	Function 2
PCTO	1.50906	-.65354	.590*	-.106
LRTIME	.32659	-.37946	.469*	-.126
RUNTIME	-.96630	.57694	.435*	-.322
VEL	.36783	-.36985	-.432*	.426
PCTVBS	.63162	.24374	.233*	-.021
CPDEV	.69227	-.00420	.240*	-.054
LRDEV	-.03585	.00228	.183*	-.052
PLANTIME	-.05302	-.04025	.164*	.083
FUEL	-.39287	-.01426	.118*	-.014
DISTANCE	.45308	-.07399	.094*	-.070
NBC	-.33808	-.29459	-.081*	.023
PCTMAP	.40083	1.04840	.267	.645*
MOVE	-1.08702	1.10948	-.095	.385*
TCCOM	.12426	-.14451	.194	-.254*
DVRCOM	-.04389	-.54442	.080	-.168*

Appendix E

Platoon Tactical Mission Analyses: Univariate Tests of Homogeneity of Variance

Table E-1

Univariate Tests of Homogeneity of Variance
for Platoon Mission Measures of Effectiveness

Measure	Cochran's C	p	Bartlett-Box	p
MSNSDONE	.3333	1.000	.000	1.000
NODONE	.8113	.016	3.813	.023
MSNTIME	.5787	.313	.693	.501
MSNFUEL	.3998	1.000	.088	.916
MSNDIST	.6883	.106	2.114	.122
MSNDISP	.9969	.000	19.390	.000
MSNSRA	.9999	.000	36.533	.000
MSNSRT	.7863	.026	2.577	.078
MSNARTA	.5947	.273	1.683	.187
MSNARTT	.4675	.692	.228	.797
MSNSTA	.4688	.687	.913	.402
MSNSTT	.4254	.883	.349	.705
FRAGDONE	.5652	.350	1.396	.249
FRAGTIME	.6560	.152	2.635	.073
FRAGFUEL	.6977	.095	2.249	.107
FRAGDIST	.6031	.254	.990	.373
MSNPCT0	.4638	.708	.322	.725
MSNTCCOM	.4662	.698	.239	.788
MSNDVRCOM	.4845	.622	.257	.774
MSNVBS	.4307	.858	.455	.635
MSNMAP	.7126	.079	4.909	.008

Appendix F

Task Difficulty Questionnaire Analyses:
Univariate ANOVAs

Table F-1

Summary of Univariate ANOVAs
for the Task Difficulty Questionnaire Measures

Planned Comparison: POSNAV-G and POSNAV-T vs. POSNAV-C

Task	Value	Std. Err.	T-Value	df	p
SIM1	6.900	.720	9.581	57	.000
SIM2	4.100	.880	4.657	57	.000
SIM3	4.050	.950	4.265	57	.000
SIM4	4.200	.816	5.150	57	.000
SIM5	3.600	1.051	3.424	57	.001
SIM6	4.600	.721	6.379	57	.000
SIM7	.600	.982	.611	57	.544
SIM8	2.900	.687	4.222	57	.000
SIM9	4.400	1.019	4.331	57	.000
SIM	3.93	.60	6.57	57	.000
TANK1	-2.250	.699	-3.651	57	.001
TANK2	-2.250	.784	-2.868	57	.006
TANK3	-2.100	.770	-2.728	57	.008
TANK4	-2.000	.822	-2.433	57	.018
TANK5	-.750	.778	-.964	57	.339
TANK6	-2.950	.821	-3.593	57	.001
TANK7	-.450	.873	-.515	57	.608
TANK8	-2.350	.817	-2.876	57	.006
TANK9	-2.400	.906	-2.648	57	.010
TANK	-1.98	.53	-3.73	57	.000
SIMTANK1	9.450	1.036	9.121	57	.000
SIMTANK2	6.350	1.293	4.910	57	.000
SIMTANK3	6.150	1.365	4.505	57	.000
SIMTANK4	6.200	1.052	5.895	57	.000
SIMTANK5	4.35	1.31	3.31	57	.002
SIMTANK6	7.550	1.126	6.708	57	.000
SIMTANK7	1.050	1.299	.808	57	.422
SIMTANK8	5.250	.991	5.295	57	.000
SIMTANK9	6.800	1.276	5.327	57	.000
SIMTANK	5.91	.793	7.45	57	.000

Table F-1 (continued)

Summary of Univariate ANOVAs
for the Task Difficulty Questionnaire Measures

Planned Comparison: POSNAV-G vs. POSNAV-T

Task	Value	Std Error	T-Value	df	p
SIM1	-.600	.416	-1.443	57	.000
SIM2	-.300	.508	-.590	57	.557
SIM3	-.550	.548	-1.003	57	.320
SIM4	-.500	.471	-1.062	57	.293
SIM5	-1.200	.607	-1.977	57	.053
SIM6	-.800	.416	-1.92	57	.060
SIM7	-.300	.567	-.529	57	.599
SIM8	-.700	.397	-1.765	57	.083
SIM9	-.900	.587	-1.53	57	.130
SIM	-.650	.345	-1.88	57	.065
TANK1	.250	.403	.620	57	.538
TANK2	.150	.453	.331	57	.742
TANK3	.100	.445	.225	57	.823
TANK4	-.300	.475	-.632	57	.530
TANK5	.450	.449	1.000	57	.321
TANK6	.150	.474	.316	57	.753
TANK7	-.550	.504	-1.090	57	.280
TANK8	-.450	.472	-.954	57	.344
TANK9	-.400	.523	-.764	57	.448
TANK	-.067	.306	-.219	57	.828
SIMTANK1	-.850	.598	-1.421	57	.161
SIMTANK2	-.450	.747	-.603	57	.549
SIMTANK3	-.650	.788	-.825	57	.413
SIMTANK4	-.200	.607	-.329	57	.743
SIMTANK5	-1.650	.759	-2.175	57	.034
SIMTANK6	-.950	.650	-1.462	57	.149
SIMTANK7	.250	.750	.333	57	.740
SIMTANK8	-.250	.572	-.437	57	.664
SIMTANK9	-.500	.737	-.678	57	.500
SIMTANK	-.582	.458	-1.27	57	.209

Appendix G

POSNAV Soldier-Machine-Interface Questionnaire Results: Means, Standard Deviations, Frequency Distributions, and *t* Test Analyses

Table G-1

POSNAV SMI Survey Questions: Overall Means, Standard Deviations, and Frequency Distributions

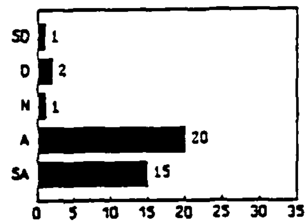
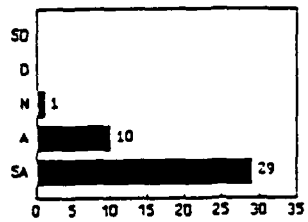
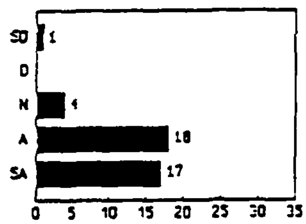
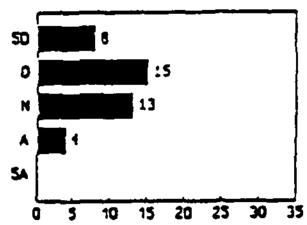
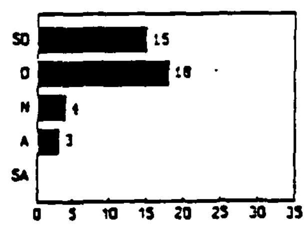
<table>
<tr><th>POSNAV SMI Survey Question</th><th>M</th><th>SD</th><th>Response Distribution</th></tr>
<tr><td>1. The location of the POSNAV TC's display in the M1 simulator was acceptable.</td><td>4.18</td><td>.914</td><td>
</td></tr>
<tr><td>2. I could easily navigate from one point to another using only the POSNAV Driver's "Steer-to" display.</td><td>4.70</td><td>.516</td><td>
</td></tr>
<tr><td>3. When navigating, the POSNAV map automatically scrolls at an acceptable rate.</td><td>4.25</td><td>.840</td><td>
</td></tr>
<tr><td>4. The POSNAV map at the 1:25,000 scale (about 3 km by 3 km) is difficult to read.</td><td>2.33</td><td>.917</td><td>
</td></tr>
<tr><td>5. The POSNAV map at the 1:50,000 scale (about 5 km by 5 km) is difficult to read.</td><td>1.88</td><td>.883</td><td>
</td></tr>
</table>

Table G-1 (continued)

POSNAV SMI Survey Questions: Overall Means, Standard Deviations, and Frequency Distributions

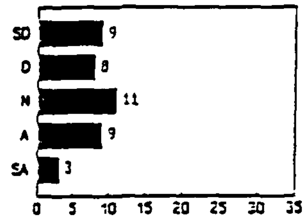
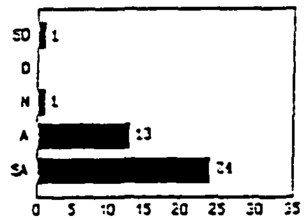
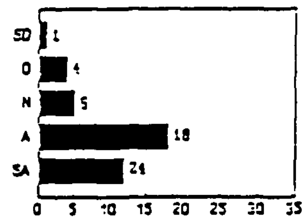
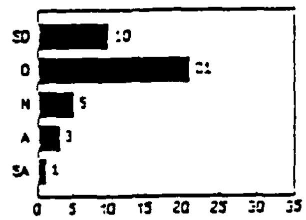
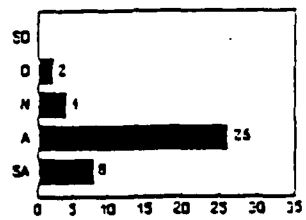
POSNAV SMI Survey Question	M	SD	Response Distribution
6. The POSNAV map at the 1:125,000 scale (about 11 km by 11 km) is difficult to read.	2.73	1.261	
7. I could easily read the information on the POSNAV display.	4.51	.790	
8. The touch screen was easy to use to select POSNAV menu options.	3.90	1.033	
9. The POSNAV display is too small.	2.10	.955	
10. The location of the POSNAV "Own Location" window is acceptable.	4.00	.716	

Table G-1 (continued)

POSNAV SMI Survey Questions: Overall Means, Standard Deviations, and Frequency Distributions

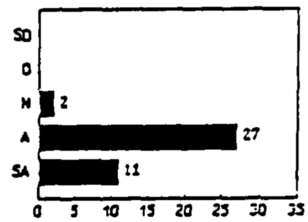
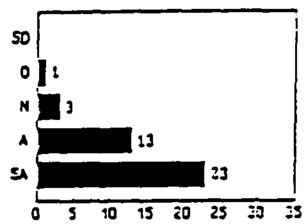
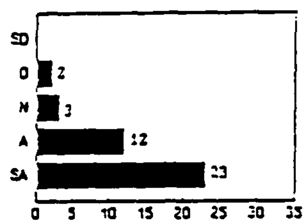
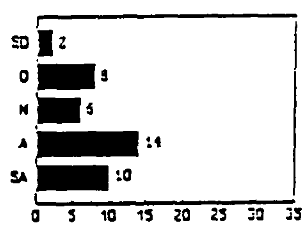
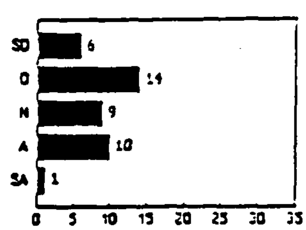
POSNAV SMI Survey Question	M	SD	Response Distribution
11. The location of the POSNAV "Main Menu" is acceptable.	4.23	.530	
12. The POSNAV "Route Designation" function is easy to use.	4.45	.749	
13. The POSNAV map is more helpful for navigating in SIMNET than a paper map.	4.40	.841	
14. I rarely used my paper map for navigating.	3.55	1.218	
15. I spent more time looking at the POSNAV display than I did looking through the vision blocks and sights.	2.65	1.099	

Table G-1 (continued)

POSNAV SMI Survey Questions: Overall Means, Standard Deviations, and Frequency Distributions

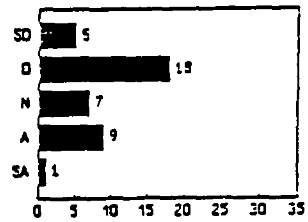
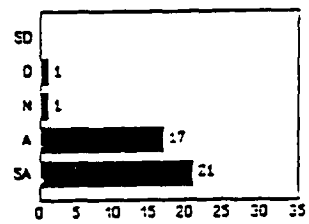
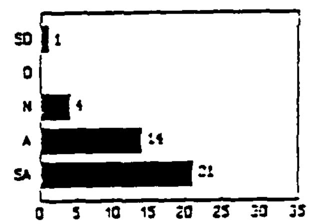
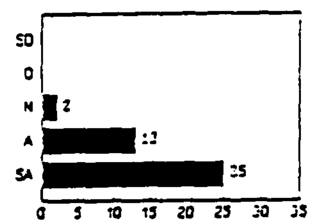
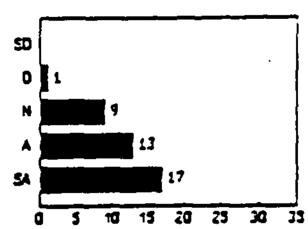
POSNAV SMI Survey Question	M	SD	Response Distribution
16. I spent more time looking at the POSNAV display than I tactically should have.	2.58	1.059	
17. I gave the driver more control over the navigation of the tank than I would have without the POSNAV display.	4.45	.677	
18. I spent less time communicating with the driver than I would have without the POSNAV display.	4.35	.864	
19. The POSNAV tank icon was useful for orienting my tank in the proper direction.	4.58	.594	
20. The MAP "Zoom" function waseasy to use.	4.15	.864	

Table G-1 (continued)

POSNAV SMI Survey Questions: Overall Means, Standard Deviations, and Frequency Distributions

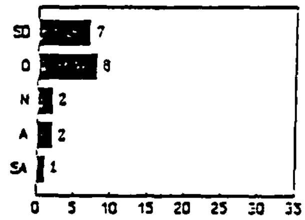
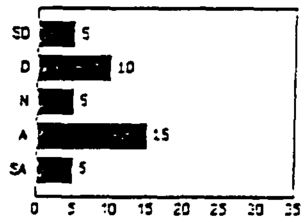
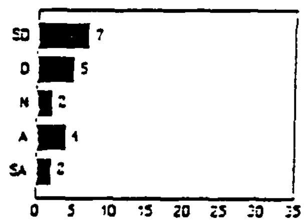
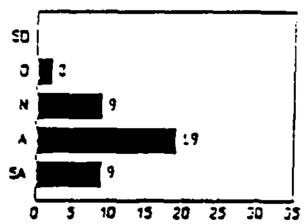
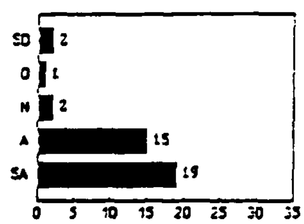
POSNAV SMI Survey Question	M	SD	Response Distribution
21. The MAP "Features" function was easy to use.	2.10	1.165	
22. I rarely changed the scale of the POSNAV map.	3.13	1.285	
23. I frequently changed the terrain features which appeared on the POSNAV map.	2.45	1.432	
24. The POSNAV map "Scroll-Type In" function was easy to use.	3.90	.321	
25. When navigating the current own-vehicle location an update rate of every 10 meters is acceptable.	4.20	1.043	

Table G-1 (continued)

POSNAV SMI Survey Questions: Overall Means, Standard Deviations, and Frequency Distributions

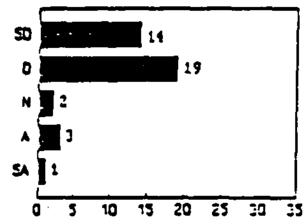
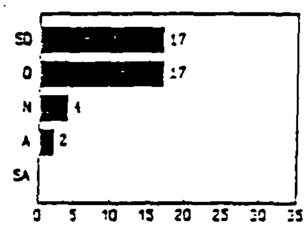
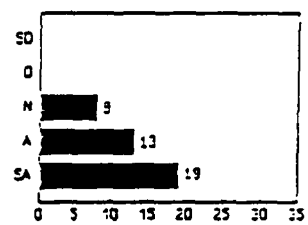
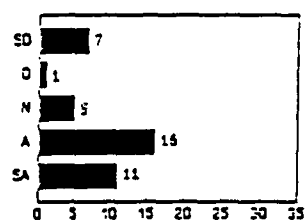
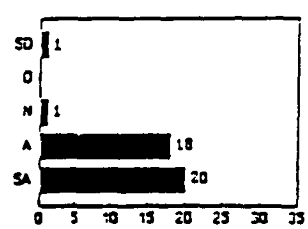
POSNAV SMI Survey Question	M	SD	Response Distribution
26. The POSNAV display functions were difficult to use while on the move.	1.92	.984	
27. The POSNAV display information was difficult to read while on the move.	1.78	.832	
28. With POSNAV, I had more time to acquire enemy targets.	4.28	.784	
29. The POSNAV system replaces theneed for a compass for landnavigation.	3.58	1.394	
30. I could easily enter waypoint grid coordinates for the POSNAV "Route Designation" function.	4.40	.778	

Table G-1 (continued)

POSNAV SMI Survey Questions: Overall Means, Standard Deviations, and Frequency Distributions

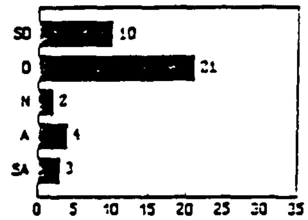
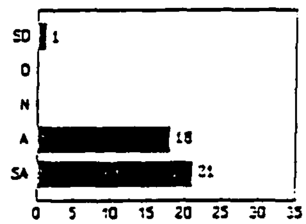
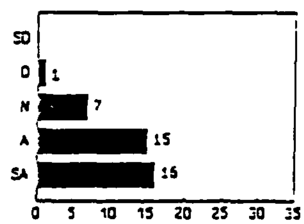
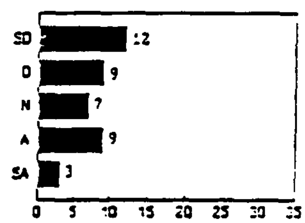
POSNAV SMI Survey Question	M	SD	Response Distribution
31. I had a difficult time changing or deleting POSNAV "Route Designation" waypoint entries.	2.23	1.165	
32. I could easily send waypoint data to the POSNAV Driver's "Steer-to" display.	4.45	.749	
33. The POSNAV map "Zoom" function was easy to use.	4.18	.823	
34. POSNAV waypoint updating should be under the driver's control.	2.55	1.339	

Table G-2

Means, Standard Deviations, and t Tests for POSNAV SMI Questionnaire Items

SMI Question	POSNAV-G (n = 20)		POSNAV-T (n = 20)		t(1,38)	p
	M	SD	M	SD		
Item 1	4.30	.80	4.30	1.49	.00	1.000
Item 2	4.60	.50	4.80	.52	-1.23	.225
Item 3	4.40	.68	4.10	.97	1.13	.264
Item 4	2.60	.82	2.05	.95	1.97	.057
Item 5	2.10	.91	1.65	.81	1.65	.108
Item 6	2.50	1.05	2.95	1.43	-1.13	.264
Item 7	4.85	1.14	4.40	.94	1.36	.181
Item 8	3.80	1.01	4.00	1.08	-.61	.547
Item 9	2.10	.85	2.10	1.07	.00	1.000
Item 10	3.90	.85	4.10	.55	-.88	.384
Item 11	4.15	.59	4.30	.47	.89	.378
Item 12	4.55	.60	4.35	.88	.84	.406
Item 13	4.10	1.02	4.70	.47	-2.39	.022
Item 14	3.45	1.19	3.65	1.27	-.51	.610
Item 15	2.45	1.10	2.85	1.09	-1.16	.255
Item 16	2.30	.92	2.85	1.13	-1.68	.101
Item 17	4.60	.50	4.30	.80	1.42	.164
Item 18	4.40	.82	4.30	.80	.36	.719
Item 19	4.55	.69	4.60	.50	-.26	.794
Item 20	4.10	.97	4.20	.77	-.36	.719
Item 21	*	*	2.10	1.16	*	*
Item 22	3.20	1.15	3.05	1.43	.37	.717
Item 23	*	*	2.45	1.43	*	*
Item 24	4.15	1.42	3.90	.79	.69	.496
Item 25	4.30	.98	4.10	1.12	.60	.551
Item 26	2.40	1.96	1.80	.69	1.29	.204
Item 27	1.90	.91	1.65	.74	.95	.348
Item 28	4.10	.72	4.45	.83	-1.43	.161
Item 29	3.60	1.43	3.55	1.40	.11	.911
Item 30	4.45	.94	4.35	.59	.40	.690
Item 31	2.15	1.13	2.30	1.22	-.40	.689
Item 32	4.30	.92	4.60	.50	-1.28	.210
Item 33	4.30	1.42	4.30	.73	.00	1.000
Item 34	2.50	1.40	2.60	1.31	-.23	.817

* This item is only applicable to POSNAV-T tank crews.